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AN ASSESSMENT OF AUTOMATIC SEWER FLOW SAMPLERS – 1975

Municipal Environmental Research Laboratory
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AN ASSESSMENT OF AUTOMATIC

SEWER FLOW SAMPLERS - 1975

by

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FOREWORD

Man and his environment must be protected from the adverse effects of pesticides, radiation, noise, and other forms of pollution, and the unwise management of solid waste. Efforts to protect the environment require a focus that recognizes the interplay between the components of our physical environment--air, water, and land. The Municipal Environmental Research Laboratory contributes to this multidisciplinary focus through programs engaged in

- studies on the effects of environmental contaminants on the biosphere, and

- a search for ways to prevent contamination and to recycle valuable resources.

The deleterious effects of storm and combined sewer overflows upon the nation's waterways have become of increasing concern in recent times. Efforts to alleviate the problem depend upon accurate characterization of these flows in both a quantity and quality sense. This report presents a state-of-the-art survey of automatic wastewater sampling devices that might be appropriate for the quality measurement of stormwater and combined sewer flows as well as other wastewater discharges, and will be of interest to those who have a requirement for the characterization of such flows.

Louis W. Lefke
Acting Director
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PREFACE

This report represents a revision and update of an earlier report, "An Assessment of Automatic Sewer Flow Samplers," published as Environmental Protection Technology Series Report No. EPA-R2-73-261, June 1973, which is hereby superseded. The major areas of change are in the descriptions of commercially available equipment, which have been revised to reflect equipment changes and new offerings that have appeared since the preparation of the original report in the fall of 1972. Additional project experience and reviews of custom designed samplers have also been given, and some modifications have been made to other portions of the text to reflect new material. As a result, over 80 percent of the present report represents new or revised content as compared to its predecessor.

Mention should be made of a collateral effort reported in "Design and Testing of a Prototype Automatic Sewer Sampling System," which is to be published soon as an Environmental Protection Technology Series Report. It describes the design implementation of a new, improved prototype automatic sampling system specifically intended for storm and combined sewers. Covered also are the results of preliminary field testing of the prototype device as well as extensive controlled laboratory testing using synthetic sewage flows. The results of side-by-side comparative testing of the prototype device and four popular commercial designs is also given, and should be of interest to the reader of the present report.

ABSTRACT

A brief review of the characteristics of storm and combined sewer flows is given followed by a general discussion of the purposes for and requirements of a sampling program. The desirable characteristics of automatic sampling equipment are set forth and problem areas are outlined.

A compendium of 82 model classes covering over 200 models of commercially available and custom designed automatic samplers is given with descriptions and characterizations of each unit presented along with an evaluation of its suitability for a storm and/or combined sewer application.

A review of field experience with automatic sampling equipment is given covering problems encountered and lessons learned. A technical assessment of the state-of-the-art in automatic sampler technology is presented, and design guides for development of a new, improved automatic sampler for use in storm and combined sewers are given.

This report was submitted in partial fulfillment of Contract Number 68-03-0409 under the sponsorship of the Municipal Environmental Research Laboratory (formerly the National Environmental Research Center), Office of Research and Development, United States Environmental Protection Agency. Work was completed in February, 1975.

CONTENTS

CONTENTS (Cont'd)

FIGURES

FIGURES (Cont'd)

TABLES

INDEX OF COMMERCIALLY AVAILABLE SAMPLERS

INDEX OF COMMERCIALLY AVAILABLE SAMPLERS (Cont'd)

INDEX OF COMMERCIALLY AVAILABLE SAMPLERS (Cont'd)

INDEX OF CUSTOM DESIGNED SAMPLERS

ACKNOWLEDGEMENTS

The cooperation and support of the commercial manufacturers and suppliers of automatic liquid sampling equipment and their representatives is acknowledged with sincere thanks. They supplied information about their current products and proposed new developments, took time to answer questions and provide operational insights, and made the preparation of much of this report possible. All equipment illustrations were provided by the respective manufacturers, and appreciation for their use in this report is hereby acknowledged.

The encouragement, cooperation, and support of users of automatic samplers, including EPA Surveillance and Analysis Division personnel (and especially Messrs. W. J. Keffer - Region VII, M. D. Lair - Region IV, and F. P. Nixon - Region II), is deeply appreciated. They freely gave of their time to discuss problems with individual pieces of equipment, to provide insights into many difficulties of field use, and to share their views on where equipment improvements were desired.

The support of this effort by the Storm and Combined Sewer Section (Edison, New Jersey) of the EPA Municipal Environmental Research Laboratory, Cincinnati, Ohio, and especially Mr. Richard Field and Mr. Hugh E. Masters, Project Officers, for their guidance, suggestions and inputs, and thorough manuscript review is acknowledged with gratitude.

SECTION I

CONCLUSIONS

1. An automatic liquid sampler is one tool of several commonly employed for the characterization of a flow stream. Its selection must be based upon consideration of the overall sampling program to be undertaken, the characteristics of the flows to be sampled, the physical characteristics of the sampling sites, and the sample analyses that are available and desired.

2. In view of the large number of highly variable parameters associated with the storm and combined sewer application, no single automatic sampler can exist that is universally applicable with equal efficacy. Some requirements are conflicting, and a careful series of trade-off studies is required in order to arrive at a "best" selection for a particular program. Such a selection may not be well suited for a different program, and a systems approach is required for either the selection or design of automatic sampling equipment for storm and combined sewer application.

3. The proper selection of sampling sites can be as important as the selection of sampling methods and equipment. A clear understanding of the data requirements and ultimate use is necessary as is a familiarity with the sewer system to be examined.

4. Over 40 prospective manufacturers of automatic liquid sampling equipment were contacted. Although some omissions undoubtedly have been made, it is felt that all major principles and techniques commercially available today have been included. These automatic samplers have been individually described and evaluated for application in a storm and/or combined sewer sampling program. Most of the units surveyed were not designed for such use, and many manufacturers do not recommend them for such applications.

5. Although certain commercially available automatic samplers may be suitable for certain storm and/or combined sewer sampling programs, no single unit appears eminently suitable for such an application. Improvements in intake design, sample intake and transport velocity, line sizes, and sample capacity appear warranted.

6. A number of custom designed, one-of-a-kind automatic samplers were reviewed and evaluated for application in a storm and/or combined sewer sampling program. Although some of these embodied fairly clever innovations, they were generally tailored around local peculiarities of the application site or program. None was deemed ideally suited for broad scale use as a storm or combined sewer sampling unit.

7. Field experience with automatic sampling equipment was reviewed with emphasis on recent EPA projects. Leaks in vacuum operated units; faulty automatic starters; inlet blockage and line plugging; limited suction lift; low transport velocities; complicated electrical systems; and failures of timers, micro-switches, relays and contacts, and reed switches were among the difficulties frequently encountered.

8. There is a plethora of sampling devices available in the marketplace today. These automatic samplers are of various designs and capabilities and incorporate both good and poor features. There are numerous claims (and counter-claims) made by the various manufacturers and their representatives, including limited data in certain instances, as to the efficacy of one particular piece of equipment (i.e., design approach) or another. The present state of affairs can be summarized as follows:

   (a) Comparisons of water quality data gathered using different commercially available samplers demonstrate without question that there can be marked differences in results obtained with different types of equipment;

   (b) Different wastewater flow characteristics call for different equipment requirements in order to assure representative sampling;

   (c) The results of manual sampling are extremely methodologically dependent, and data strongly indicate that they may or may not be representative of the wastewater flow in question; and

   (d) No satisfactory way has yet been developed to meaningfully and uniformly evaluate the performance capabilities of automatic sample collection systems.

9. One of the greatest problem areas is in the design of a sampler intake that can gather a representative sample, even in a stratified flow condition, and at the same time be relatively invulnerable to clogging or damage due to solids or debris in the flow stream. Separate considerations are required for intakes to be used for sampling floatables (especially oil and grease) or coarser bottom solids including bed load. Some generally desirable sampler intake characteristics include:

   (a) Sample intake velocity should equal or exceed the velocity of the stream being sampled;

   (b) Intake geometry such as diameter, beveled inside or outside, radiused, etc., is not critical insofar as sampling representativeness is concerned;

   (c) Gravity filled intakes usually have a varying sample intake velocity which is undesirable in most instances; and

   (d) The sampler intake should prevent ingestion of unwanted material that could clog or damage other portions of the sampler.

10. Selection of the sample gathering method to be used is more site dependent than any other design attribute. The requirement to minimize obstructions to the flow eliminates most mechanical and forced flow designs from consideration. The suction lift gathering method appears to offer the most advantages and flexibility overall. The pumping portion of the unit should be separable from the remainder of the device for use at sites that exceed the recommended lift of the pump. The first flow of suction lift devices should be returned to waste unless it is part of a large sample.

11. All sample transport lines should be large enough to minimize clogging, yet small enough to assure adequate transport velocity for the largest suspended solids to be sampled. For the storm and combined sewer application, minimum line sizes of 0.95-1.27 cm (3/8-1/2 in.) inside diameter appear desirable. Minimum transport velocities of 0.6-0.9 m/s (2-3 fps) would appear warranted. The sampling train should be free of internal constrictions due to valves, fittings, etc., and have a minimum of twists and bends. It is desirable for the sample to be carried under pressure all the way to its container.

12. Composite samplers cannot represent the time history of a storm event, and consequently, discrete samplers are more often desired. The quantity of sample required is dependent upon the subsequent analyses to be performed, but at least a liter is generally desired. The sample containers should either be easy to clean or disposable. Provision for cooling the samples until they can be taken to the laboratory should be included. Immersion-proof construction is advantageous.

13. The sampler should be capable of accepting automatic start signals from some external sensor. It should have an internal timer and also be capable of being paced by an external flowmeter. For composite samplers particularly, the sample volume should be constant and not vary with lift, water level, etc. Solid-state electronics appear desirable.

SECTION II

RECOMMENDATIONS

1. There is an urgent need for determining the capabilities of various types of sample collection systems to gather representative samples of wastewater flows over a wide range of characteristics. This must be done under controlled conditions if results are to be quantified in any way other than as relativistic comparisons. It is recommended that a number of sample collection systems of the types that represent the majority of present day equipment be assembled and tested under controlled laboratory conditions representing a wide range of wastewater flow characteristics.

2. There is at present no well-defined manual sampling protocol. It is recommended that equipment and procedures be developed that will allow representative samples to be gathered from a variety of sites under a wide range of wastewater flow characteristics.

3. There are no specific guides to aid a would-be purchaser of automatic wastewater sampling equipment generally available at the present time. It is recommended that performance specifications and standard testing and acceptance procedures be developed for a number of classes of wastewater, including stormwater and combined sewage.

4. Representative sampling of bed load and floatables (including oil and grease) continues to be an extremely difficult problem. It is recommended that a program to develop equipment that is suitable for these purposes be initiated in the near future.

5. In view of the potential for increase in commercially available equipment and changes and improvements introduced by manufacturers subsequent to the publication of this report, it is recommended that it be updated in two years.

SECTION III

INTRODUCTION

"By a small sample we may judge of the whole."

Cervantes (1605)

Since the very beginnings of primitive man's existence he has been faced with the necessity to sample, his first experiences probably being in the area of food and water selection. The need to sample arises from a data requirement that is necessary in order to make some judgmental decision and presumes the unavailability of the whole. If the data which are to be derived from the sample are to be efficacious in terms of the judgmental decision to be made however, it is necessary that the sample be truly representative of the whole, at least insofar as those parameters which are of interest are concerned. It is this requirement, which arises from the nature of the data sought, that must be the overriding consideration in any sampling effort.

As the civilization of man continued, the exigencies of social awareness and community led to cooperative sampling and judgmental decisions affecting others as well as the sampler himself. In particular, man's requirement for water to maintain his existence and his concern for the quality of this water have partially shaped the course of history and given rise to more formal sampling programs for the common good. The records of ancient civilizations attest to the difficulties man has experienced in obtaining an adequate supply of water, protecting its quality, dealing with sediment transport in natural water courses, and the like. An excellent historical review of water sampling, especially as related to suspended sediment, is given in (1). Suffice it to note here that despite the fact that the first sampling for water quality is lost in the antiquity of man's development, it was not until the early part of the nineteenth century that documentation can be found of the formal sampling efforts of Gorsse and Subuors in the Rhone River in 1808 and 1809.

From such humble beginnings, reinforced by technology and man's increased awareness of his environment and his need to protect it, have arisen even more demanding requirements for water sampling programs and for equipment to carry them out. Today a large number of companies have been formed to produce sampling equipment, and it is to their products that much of the present report will be directed.

PURPOSE AND SCOPE

This report is intended to present a current review of the state-of-the-art and assessment of sampling equipment and techniques. Particular emphasis has been placed on automatic liquid samplers which are commercially available today in the American marketplace. These are described and evaluated in terms of their suitability for use in storm or combined sewer applications. However, a sampling device which is suitable for such applications will most likely suffice for any other municipal wastewater application as well. By collecting and presenting such a review it is hoped that shortcomings and limitations of these devices for such applications can be overcome and that this report can serve as a springboard for the development of new and/or improved devices. In order to assess the probable effectiveness of an existing device for sampling sewage in storm sewers and/or combined sewers, or to select criteria for the design of a new or improved device, consideration of the character of such sewers and sewage is essential. Questions to be considered are: What are their general characteristics? What are the usual flow modes found in such sewers? How do the pollutant materials carried in the sewers vary with time and location?

GENERAL CHARACTER OF SEWAGE

Knowledge of the character of the urban environment leads one to the expectation that stormwater draining from it will be of poor quality. Washings from the sidewalks, streets, alleys, and catch basins are a part of the runoff and include significant amounts of human and animal refuse. In industrial areas, chemicals, fertilizers, coal, ores, and other products are stockpiled exposed to rainfall, so that a significant quantity of these materials appears in the runoff. Extreme quantities of organic materials such as leaves and grass cuttings often appear in storm sewers. In the fall, such sewers at times become almost completely filled with leaves. Often during storms large boards, limbs, rock, and every imaginable kind of debris appear in the sewers, probably as a result of breaks in the sewers and/or accessory equipment designed to screen out the larger items. One of the heaviest pollution loads is that of eroded silts and sediments washed from the land surface. Much of this is from construction areas where the land has been disturbed prior to completion of streets and buildings and reestablishment of plant life. Finally, a significant amount of solids found in storm runoff originates as dustfall from air pollution. According to studies made in Chicago (2), about 3 percent of the total solids load has its source in dustfall.

General observation of the polluted nature of storm runoff from urban areas is supported by a number of studies made in several large cities in the United States, and in Oxney, England; Moscow and Leningrad, U.S.S.R.; Stockholm, Sweden; and Pretoria, South Africa. In (2) the American Public Works Association states, "Stormwater runoff has been found in many instances to be akin to sanitary sewage in its pollutional characteristics and in a few instances some parameters of pollution are even greater". Table 1, which is taken from (5), contains selected data on the characteristics of urban stormwater.

In some areas, sewers classed as storm sewers are, in fact, sanitary or industrial waste sewers due to unauthorized and various other connections made to them. This condition may become so aggravated that a continuous flow of sanitary sewage flows into the receiving stream. Wastes from various commercial and industrial enterprises are often diverted to these so-called storm sewers. A rather common pollutant is the flushings from oil tanks.

Combined sewers are designed and constructed to carry both stormwater and sanitary sewage and/or industrial wastes. Therefore, sewage in them has all the pollutional aspects of storm runoff as described above, but also includes the pollution load of domestic wastes.

Where industrial wastes are contributed also, a very complex sewage, with respect to both varied flow rate and pollution load, is created. The task of sampling and analyzing this creation with reasonable accuracy becomes an extremely difficult one.

Because of normal leaks at joints, pipe breaks, loss of manhole covers, and other unplanned openings to them, separate sanitary sewers often carry large flows of storm runoff and/or infiltrate. This usually occurs in sections of high ground water level, or where the sewer line is constructed in, or adjacent to, a stream bed. Under such conditions, these sewers have much the same character as combined sewers, and require the same types of sampling equipment and methods.

FLOW MODES

Storm sewers, during periods of no rainfall, often carry a small but significant flow. This may be flow from ground water, or "base flow", which gains access to the sewer from unpaved stream courses. Such base flow may appear as runoff from parks or from suburban areas where there are open drains leading to the storm sewer.

TABLE 1. Characteristics of Urban Stormwater*

Characteristic	Range of Values
BOD_5 (mg/l)	1->700
COD (mg/l)	5-3,100
TSS (mg/l)	2-11,300
TS (mg/l)	450-14,600
Volatile TS (mg/l)	12-1,600
Settleable solids (ml/l)	0.5-5,400
Organic N (mg/l)	0.1-16
NH_3N (mg/l)	0.1-2.5
Soluble PO_4 (mg/l)	0.1-10
Total PO_4 (mg/l)	0.1-125
Chlorides (mg/l)	2-25,000†
Oils (mg/l)	0-110
Phenols (mg/l)	0-0.2
Lead (mg/l)	0-1.9
Total coliforms (no./100 ml)	200-146 x 10^6
Fecal coliforms (no./100 ml)	55-112 x 10^6
Fecal streptocci (no./100 ml)	200-1.2 x 10^6

* Taken from Reference 5.

† With highway deicing.

Unfortunately, much of the flow in storm sewers during periods of no rainfall is composed of domestic sewage and/or industrial wastes. Where municipal ordinances concerning connections to sewers are not rigidly enforced, it appears to be reasonably certain that unauthorized connections to storm sewers will appear. In some cases, the runoff from septic tanks is carried to them. Connections for the discharge of swimming pools, foundation drains, sump pumps, cooling water, and pretreated industrial process water to storm sewers are permitted in many municipalities, and contribute to flow during periods of no rainfall.

Storm runoff is the excess rainfall which runs off the ground surface after losses resulting from infiltration to ground water, evaporation, transpiration by vegetation, and ponding occur. A small portion of the rainfall is held in depression storage, resulting from small irregularities in the land surface. The quantity, or rate of flow, of such runoff varies with intensity, duration, and areal distribution of rainfall; character of the soil and plant life; season of the year; size, shape, and slope of drainage basin, and other factors. Ground seepage loss varies during the storm, becoming less as the ground absorbs the water. The period of time since the previous, or antecedent, rainfall significantly affects the storm runoff.

In general, storm runoff is intermittent in accordance with the rainfall pattern for the area. It is also highly variable from storm to storm and during a particular storm.

The design capacity of storm sewers is based on the flow due to a storm occurring, on the average, once in a selected number of years (recurrence interval). Usually a recurrence interval not greater than 10 years is selected for the design of underground storm sewers. As a result, the design capacity of the sewer is exceeded at comparatively frequent intervals, resulting in surcharging and flooding of the overlying surface.

Flow in combined sewers during periods of no rainfall is called dry-weather flow. This is the flow of sanitary sewage and/or industrial wastes, and often includes infiltrated ground water. As the sewer is designed, dry-weather flow generally includes only a small portion of the total sewer capacity, on the order of 10% in the larger sewer sizes. However, due to overloading in many rapidly developing areas, the dry-weather flow sometimes requires a much larger percentage of total capacity. The storm runoff portion of the flow in combined sewers is as described above for storm sewers. However, the design capacity for carrying storm runoff is probably less than is usually provided for storm sewers.

Sewers for intercepting dry-weather flow from a system of combined sewers for transport to a point for treatment or disposal have been designed for enough capacity to include a portion of the stormwater in the system. In the United States, this interceptor capacity ranges from two to four times the dry-weather flow. A weir or other regulating device controls the flow of sewage to the interceptor by diverting the flow above a pre-selected stage to an overflow line. The excess flows, or overflows, are carried to some external channel, such as a creek or river. Thus, raw sewage is carried to the streams with storm runoff during periods of rainfall.

VARIABILITY OF POLLUTANT CONCENTRATION

The pollutant concentration in storm and combined sewers is highly variable, both with respect to the time and with the position in the sewer cross-section. This is true during periods of no rainfall as well as during storm runoff periods, but usually to a lesser extent.

Variability with Time

Probably the most constant character of pollutants occurs in storm sewers when all flow is base flow derived from ground water. Because of the slow movement of water through the ground, changes in concentration of pollutants occur only during relatively long time periods. Where unauthorized connections of domestic sewage and industrial waste lines to storm sewers are found, rapid fluctuations of concentration with time may occur. The domestic sewage constituent varies with time of day, with season of the year, and probably over long-term periods. Industrial wastes vary with specific processes and industries. Very rapid changes may occur with plant shift changes and with process dynamics. Conditions on weekends and holidays may be very different from those on regular work days.

Observation and experience have demonstrated that the heaviest concentration of suspended solids during periods of storm runoff usually occurs during the early part of the storm. At this time, the stage is rising and accumulated dry-weather solid residue is being flushed from the sewers and washed and eroded from the tributary land areas. As runoff recedes, the sewer and land area surfaces exposed to flow are reduced, the flow velocities which serve to flush and erode are decreased, and the more easily dislodged solids have been acted upon. Thus, suspended material is reduced in concentration. This pattern of variation may not be followed during a period of storm runoff which immediately follows a previous storm runoff period because the land surface and sewer lines are relatively clean.

Pollutants derived from point sources, such as those from stockpile drainage, vary at the sampling location with time of travel from the source to the point of observation. Maximum concentration may occur after the peak of storm runoff. It is conceivable that there would be no contribution from some point sources during a specific storm because of areal variation of rainfall in the basin.

The variability of concentration of pollutants in combined sewer dry-weather flow is similar to that of storm sewers having unauthorized connections of domestic sewage and/or industrial waste lines. The fluctuations in domestic sewage and industrial waste concentration are discussed above.

Variability with Position in the Sewer Cross-Section

Many factors influence the variability of composition with position in the sewer cross-section. Among them are:

(a) Turbulent flow (as opposed to laminar) which occurs at the velocities and with the boundary conditions found in sewers, is particularly high during periods of storm runoff. A description of these two states of flow is given by Chow (3), as follows:

> "Depending on the effect of viscosity relative to inertia, the flow may be laminar, turbulent, or transitional. In laminar flow, the water particles appear to move in definite smooth paths, or streamlines, and infinitesimally thin layers of fluid seem to slide over adjacent layers. In turbulent flow, the water particles move in irregular paths which are neither smooth nor fixed but which in the aggregate still represent the forward motion of the entire stream."

(b) Varying velocities within the section, with higher velocities near the surface and lower velocities near the bottom. Average velocity in the vertical is at about

0.6 depth. Velocities are higher near the center of the pipe or conduit than near the outer boundaries. Such velocity distributions are generally characteristic of open-channel flow conditions, but are not all necessarily valid when the sewer becomes surcharged.

(c) The tendency for flows transporting materials of different density, and having different temperatures, to remain separate from each other for quite some distance following their convergence.

(d) The fact that substances in solution may well behave independently of suspended particles. Little is known of the lateral dispersion of solutions in sewage. Conversions from solution to suspension, and the reverse, would occur under some conditions.

(e) Vertical drops, chutes, or hydraulic jumps a short distance upstream from the section which will produce violent turbulence, resulting in improved distribution of suspended solids in the cross-section.

Suspended solids heavier than water have their lowest concentrations near the surface, and the concentration increases with depth. Near the bottom of the sewer may occur a "bed load" composed almost entirely of heavier solids. This may "slide" along the bottom or, with insufficient flow velocity, may rest on the bottom. As the velocity and turbulence increase, the "bed load" may be picked up and suspended in the sewage.

At the beginning of storm runoff, as water picks up solids which have accumulated in the sewer upstream during periods of no rainfall, the flow may be composed largely of sewage solids, or "bed load", which appears to be pushed ahead by the water.

Suspended materials lighter than water, such as oils and greases, float on the surface, as do leaves, limbs, boards, bottles, and cloth and paper materials. Other small, light particles are moved randomly within the flow by turbulence. These may be well distributed in the cross-section without significant effect of variable velocity within the section.

Larger, heavier suspended and floating solids tend to move to the outside of a horizontal curve as a result of centrifugal inertia force. Particles with a specific gravity much less than 1.00 may tend to move toward the inside of the curve. Because the effect of curvature on flow often continues downstream a considerable distance, it is probable that a normal distribution of suspended matter is not found on a curve, or downstream for a distance of several sewer widths.

Incoming sewage from an upstream lateral with different density and temperature may not mix well, and often flows for long distances without combining with the main body of the sewer. The appearance may be of two streams flowing side-by-side, each with different quality characteristics. A sample taken from either stream is not representative of the entire stream character.

SECTION IV

REQUIREMENTS AND PURPOSES OF SAMPLING

Sampling of sewage is performed to satisfy various purposes and requirements. These include the planning, design and operation of facilities for the control and treatment of sewage; the enforcement of water quality standards and objectives; and general research to increase our knowledge of the characterization of sewage.

Development of a program of sampling is presently based on a limited number of properties and constituents for which analyses are made. The type of sample collected depends on the purpose of the program, and on both technical and economic considerations.

COMMON PROPERTIES AND CONSTITUENTS

Although the constituents of sewage include most substances known to man, there are a limited number of measurements made to determine the more common properties and constituents. Most of these are shown in Table 2, which is taken from (4).

It is a practical impossibility either to perform instant analyses of a sample on the spot or to completely and unequivocally preserve it for subsequent examination. Preservative techniques can only retard the chemical and biological changes that inevitably continue following extraction of the sample from its parent source. In the former case, changes occur that are a function of the physical conditions - metal cations may precipitate as hydroxides or form complexes with other constituents; cations or anions may change valence states under certain reducing or oxidizing conditions; constituents may dissolve or volatize with time, and so on. In the latter case, biological changes taking place may change the valence state of an element or radical; soluble constituents may be converted to organically bound materials in cell structures; cell lysis may result in release of cellular material into solution, etc. Preservation methods are generally limited to pH control, chemical addition, and refrigeration. Recommendations for preservation of samples according to the measurement analysis to be performed are given in Table 2.

Figures given for sample size are generally large. For example, much smaller samples are needed with use of various systems of automatic analysis. The Technicon Auto-Analyzer

TABLE 2. Properties and Constituents of Sewage

Measurement	Vol Req (ml)	Container	Preservative	Holding Time[6]
Acidity	100	P,C[2]	Cool, 4°C	24 Hrs
Alkalinity	100	P,G	Cool, 4°C	24 Hrs
Arsenic	100	P,G	HNO_3 to pH <2	6 Mos
BOD	1000	P,G	Cool, 4°C	6 Hrs[3]
Bromide	100	P,G	Cool, 4°C	24 Hrs
COD	50	P,G	H_2SO_4 to pH <2	7 Days
Chloride	50	P,G	None Req	7 Days
Chlorine Req	50	P,G	Cool, 4°C	24 Hrs
Color	50	P,G	Cool, 4°C	24 Hrs
Cyanides	500	P,G	Cool, 4°C NaOH to pH 12	24 Hrs
Dissolved Oxygen				
Probe	300	G only	Det on site	No Holding
Winkler	300	G only	Fix on site	No Holding
Fluoride	300	P,G	Cool, 4°C	7 Days
Hardness	100	P,G	Cool, 4°C	7 Days
Iodide	100	P,G	Cool, 4°C	24 Hrs
MBAS	250	P,G	Cool, 4°C	24 Hrs
Metals				
Dissolved	200	P,G	Filter on site HNO_3 to pH <2	6 Mos
Suspended			Filter on site	6 Mos
Total	100		HNO_3 to pH <2	6 Mos
Mercury				
Dissolved	100	P,G	Filter HNO_3 to pH <2	38 Days (Glass) 13 Days (Hard Plastic)
Nitrogen				
Ammonia	400	P,G	Cool, 4°C H_2SO_4 to pH <2	24 Hrs[4]
Kjeldahl	500	P,G	Cool, 4°C H_2SO_4 to pH <2	24 Hrs[4]
Nitrate	100	P,G	Cool, 4°C H_2SO_4 to pH <2	24 Hrs[4]
Nitrate	50	P,G	Cool, 4°C	24 Hrs[4]

Measurement	Vol Req (ml)	Container	Preservative	Holding Time[6]
NTA	50	P,G	Cool, 4°C	24 Hrs
Oil and Grease	1000	G only	Cool, 4°C H_2SO_4 to pH <2	24 Hrs
Organic Carbon	25	P,G	Cool, 4°C H_2SO_4 to pH <2	24 Hrs
pH	25	P,G	Cool, 4°C Det on site	6 Hrs[3]
Phenolics	500	G only	Cool, 4°C H_3PO_4 to pH <4 1.0g $CuSO_4$/l	24 Hrs
Phosphorus				
Orthophosphate, Dissolved	50	P,G	Filter on site Cool, 4°C	24 Hrs[4]
Hydrolyzable	50	P,G	Cool, 4°C H_2SO_4 to pH <2	24 Hrs[4]
Total	50	P,G	Cool, 4°C	24 Hrs[4]
Total, Dissolved	50	P,G	Filter on site Cool, 4°C	24 Hrs[4]
Residue				
Filterable	100	P,G	Cool, 4°C	7 Days
Nonfilterable	100	P,G	Cool, 4°C	7 Days
Total	100	P,G	Cool, 4°C	7 Days
Volatile	100	P,G	Cool, 4°C	7 Days
Settleable Matter	1000	P,G	None Req	24 Hrs
Selenium	50	P,G	HNO_3 to pH 2	6 Mos
Silica	50	P only	Cool, 4°C	7 Days
Specific Conductance	100	P,G	Cool, 4°C	24 Hrs[5]
Sulfate	50	P,G	Cool, 4°C	7 Days
Sulfide	50	P,G	2 ml zinc acetate	24 Hrs
Sulfite	50	P,G	Cool, 4°C	24 Hrs
Temperature	1000	P,G	Det on site	No Holding
Threshold Odor	200	G only	Cool, 4°C	24 Hrs
Turbidity	100	P,G	Cool, 4°C	7 Days

NOTES:

1. Taken from Reference 4.
2. Plastic or Glass.
3. If samples cannot be returned to the laboratory in less than 6 hours and holding time exceeds this limit, the final reported data should indicate the actual holding time.
4. Mercuric chloride may be used as an alternate preservative at a concentration of 40 mg/l, especially if a longer holding time is required. However, the use of mercuric chloride is discouraged whenever possible.
5. If the sample is stabilized by cooling, it should be warmed to 25°C for reading, or temperature correction made and results reported at 25°C.
6. It has been shown that samples properly preserved may be held for extended periods beyond the recommended holding time.

requires samples of less than 30 ml, and is recommended for total alkalinity, chloride, cyanide, fluoride, total hardness, nitrogen (ammonia), nitrogen (Kjeldahl), nitrogen (nitrate - nitrite), phosphorus, sulfate, COD, and others.

TYPE OF SAMPLE

The type of sample collected depends on a number of factors such as the rate of change of flow and of the character of the sewage, the accuracy required, and the availability of funds for conducting the sampling program. All samples collected, either manually or with automatic equipment, are included in the following types:

1. Manual "grab" samples which are obtained by dipping a container into the sewer and bringing up a sample of wastewater. Containers are sometimes devised to grab a sample at a stationary depth or so that a sample integrated from bottom to top of the stream is collected. Water flows gradually into the container as it passes through the flow.

2. Automatic "grab", or discrete, samples which are collected at selected intervals, and each sample is retained separately for analysis. Usually each sample is collected at a single point in the sewer cross-section. However, in a few instances samplers with multiple ports have been used to allow simultaneous collection from several points in the cross-section.

3. Simple composite samples, which are made up of a series of smaller samples (aliquots) of constant volume (Vc) collected at regular time intervals (Tc) and combined in a single container. The series of samples is collected over a selected time period, such as 24 hours, or during a period of storm runoff, for example. The simple composite represents the average condition of the waste during the period only if the flow is constant.

4. Flow-proportional composite samples, which are collected in relation to the flow volume during the period of compositing, thus indicating the "average" waste condition during the period. One of two ways of accomplishing this is to collect samples of equal volume (Vc), but at time intervals (Tv) that are inversely proportional to the volume of flow. That is, the

time interval between samples is reduced as the volume of flow increases, and a greater total sample volume is collected. Flow proportioning can also be achieved by increasing the volume of each sample collected in proportion to the flow (Vv), but keeping the time interval between samples constant (Tc).

5. Manually composited samples which are obtained, where recording flow records are available, from fixed volume "grab", or discrete, samples collected at known times and proportioned manually to produce a flow proportioned composite sample.

6. Sequential composite samples, which are composed of a series of short-period composites, each of which is held in an individual container. For example, each of several samples collected during a 1-hour period may be composited for the hour. The 24-hour sequential composite is made up from the individual 1-hour composites.

ADEQUACY OF A SAMPLING PROGRAM

The adequacy of a sampling program depends largely on the optimum selection of sampling sites. Both the program cost and its effectiveness in collecting samples representative of the character of sewer flows are seriously affected by the care exercised in site selection. Similarly, the kinds of samplers selected determine the adequacy of the program with respect to obtaining suitable data for the needs of the particular sampling program.

In most cases, use of mathematical statistical analysis for determining the probable errors in the data obtained by sewer sampling is not practical. A single "grab" sample of 1 liter, even in dry-weather flows, is not necessarily indicative of the average character of the flow. With respect to an instant of time, the indicated character of the sewage may vary with the point in the cross-section from which it was "grabbed". One must consider the universe of sewage volumes represented by the sample. At the instant of sampling, it may be all the liters of sewage in the cross-section at that instant. But, if the sewage is not thoroughly mixed, we know that the sample is biased, that is, it may represent only a portion of the 1-liter samples in the cross-section, possibly only those near the surface of the flow.

In periods of storm runoff, it is known, if only by observation, that the character of the sewage is continually changing, possibly with great rapidity. There, then, becomes no single universe represented by the "grab" sample. Instead, there is an infinite number of universes, and the single "grab" sample is without meaning in determining the character of the sewage. A similar situation exists in the case of sewers carrying industrial wastes. The variability of flow and of quality parameters during periods of storm runoff are illustrated in figure 1, wherein quantity and quality data for a storm on the Bloody Run sewer watershed at Cincinnati, Ohio, are graphically presented.

It becomes apparent, then, that a large number of samples is required to adequately characterize the character of sewage in a combined sewer during and immediately after a storm event, particularly if the character is to be related to flow rate. Compositing the samples in proportion to flow rate may determine the average character of the sewage during the period of compositing. However, it does nothing to describe the pattern of changes which may occur during that period.

Awareness of the general character of sewer flows and of flow modes in storm sewers and combined sewers, and knowledge of the variability of pollutant concentration, leads to an understanding of how best to select sites for sampling. Some of the considerations in making such selections are:

1. Maximum accessibility and safety -- Manholes on busy streets should be avoided if possible; shallow depths with manhole steps in good condition are desirable. Sites with a history of surcharging and/or submergence by surface water should be avoided if possible. Avoid locations which may tend to invite vandalism.

2. Be sure that the site provides the information desired -- Familiarity with the sewer system is necessary. Knowledge of the existence of inflow or outflow between the sampling point and point of data use is essential.

3. Make certain the site is far enough downstream from tributary inflow to ensure mixing of the tributary with the main sewer.

4. Locate in a straight length of sewer, at least six sewer widths below bends.

5. Locate at a point of maximum turbulence, as found in sewer sections of greater roughness and of probable higher velocities. Locate just downstream from a drop or hydraulic jump, if possible.

6. In all cases, consider the cost of installation, balancing cost against effectiveness in providing the data needed.

Presently available sewage samplers have a great variety of characteristics with respect to size of sample collected, lift capability, type of sample collected (discrete or composite), material of construction, and numerous other both good and poor features. A number of considerations in selection of a sampler are:

1. Rate of change of sewage conditions

2. Frequency of change of sewage conditions

3. Range of sewage conditions

4. Periodicity or randomness of change

5. Availability of recorded flow data

6. Need for determining instantaneous conditions, average conditions, or both

7. Volume of sample required

8. Need for preservation of sample

9. Estimated size of suspended matter

10. Need for automatic controls for starting and stopping

11. Need for mobility or for a permanent installation

12. Operating head requirements.

Because of the variability in the character of storm and/or combined sewage, and because of the many physical difficulties in collecting samples to characterize the sewage, precise characterization is not practicable, nor is it possible. In recognition of this fact, one must guard against embarking on an excessively detailed sampling program, thus

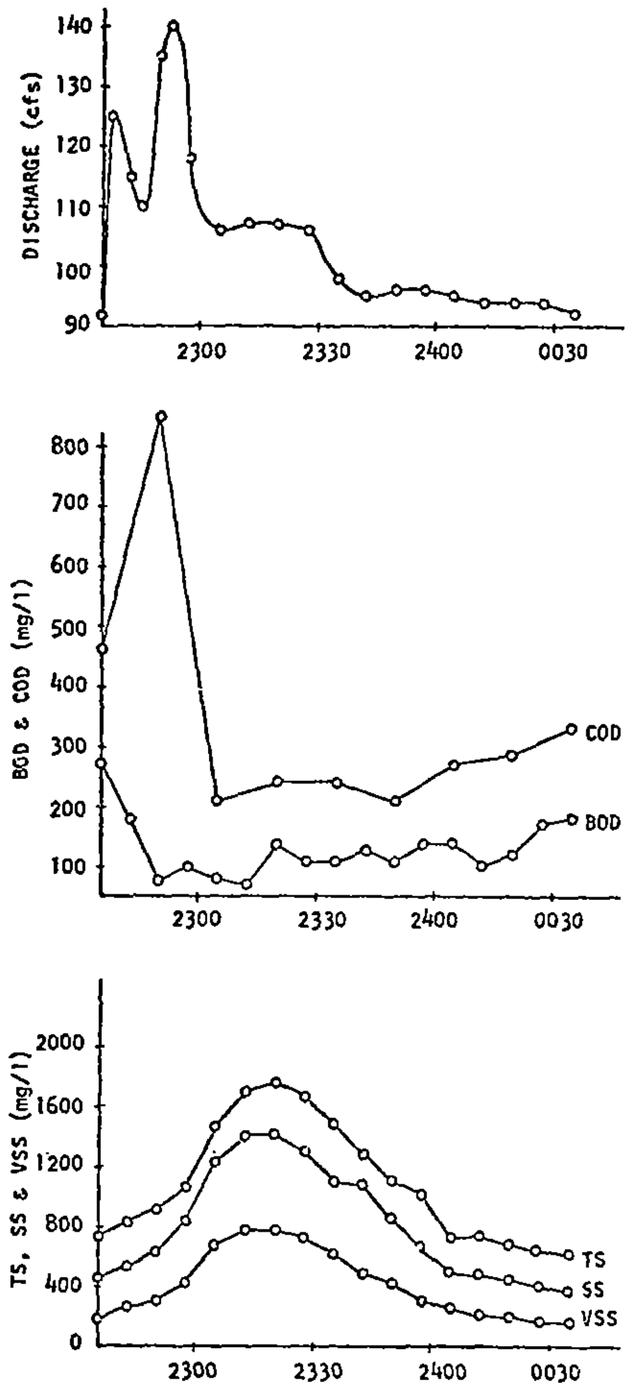

Figure 1. Runoff Quantity and Quality Data, Bloody Run Sewer Watershed*

* Taken from Reference 19

increasing costs, both for sampling and for analyzing the samples, beyond costs that can be considered sufficient for conducting a program which is adequate for the intended purpose.

A careful study of costs should be made prior to commencing a program of sampling, balancing cost against the number of samples and analyses required for adequate characterization of the wastewater. As the program progresses, current study of the results being obtained may make it reasonable to reduce or increase the number of samples collected.

The unit cost of handling and analyzing samples can often be reduced by careful planning and scheduling of field work, and by coordination with laboratory requirements. If the volume of samples is large, and the program is to continue over a long time period, consideration should be given to use of equipment for automatic analyses and in-situ monitoring. A number of equipment types and methods, such as specific ion electrodes and probes, are available for these purposes. As an example, approximately 15 samples per hour can be analyzed for chloride, using the Technicon Auto-Analyzer. Samples of only 4 ml volume are required. Caution is needed in selecting equipment suitable for a series of parameters for which analyses are to be made. With some equipment, the time required for making necessary adjustments between each of a series of tests may counteract the rapidity of making analyses for a single parameter.

SPECIFIC SAMPLING PURPOSES AND REQUIREMENTS

Sampling programs are set up for various purposes for which the requirements are not necessarily the same. That is, parameters important to one kind of project may not be needed for another project having a different objective. As an example, parameters of interest for operation of facilities for control and treatment of stormwater and/or combined sewage may be more limited in number than those needed for planning and design of the facilities. In the operation stage, experience at the particular location and with the unique facilities, may have demonstrated a more limited sampling need. On the other hand, where stormwater is combined with industrial wastes, analyses for additional parameters may be required.

A number of physical, chemical, combinations of physical-chemical, and biological methods have been considered in the Storm and Combined Sewer Pollution Control Program of the EPA for treatment of stormwater and combined sewage. In most cases, some type of control such as reduction of instantaneous peak flows is essential for practical application of treatment methods. These include storage facilities of many types, flow regulation and routing, and remote flow and overflow sensing and telemetering.

Specific processes which have been investigated are (5):

Physical - (1) Fine mesh screening; (2) Microstrainer; (3) Screening/Dissolved-air flotation; (4) High-rate single-, dual-, or tri-media filtration; (5) Swirl and helical separation; (6) Tube settlers; etc.

Chemical - (1) Coagulant and polyelectrolyte aids for sedimentation, filtration, flotation and microstraining; (2) Chemical oxidation and use of ozone for oxidation; and (3) Disinfection -- chlorination, ozonation, high rate application, on-site generation, and use of combined halogens (chlorine and iodine) and chlorine dioxide.

Physical-Chemical - (1) Screening plus dissolved-air flotation with flotation aids; (2) Screening - chemical flocculation - sedimentation - high-rate filtration; (3) Powdered and granular activated carbon adsorption; (4) Chemical flocculation - tube sedimentation - tri-media filtration; and (5) Screening - coagulation - high rate dual-media filtration.

Biological - (1) High-rate plastic and rock media trickling filters; (2) Bio-adsorption (contact stabilization); (3) Stabilization ponds; (4) Rotating biological contactor; and (5) Deep-tank aerobic and anaerobic treatment.

For planning and designing such facilities and processes, and for testing their impact on receiving streams, sampling for certain basic wastewater parameters is essential. In general these include:

1. Biochemical oxygen demand (BOD) - Used to determine the relative oxygen requirement of the wastewater. Data from BOD tests are used for the development of engineering criteria for the design of wastewater treatment plants.

2. Chemical oxygen demand (COD) - Provides additional information concerning the oxygen requirement of wastewater. It provides an independent measurement of organic matter in

the sample, rather than being a substitute for the BOD test. For combined sewer overflows and stormwater, COD may be more representative of oxygen demand in a receiving stream because of the presence of metals and other toxicants which are relatively nonbiodegradable.

3. Total oxygen demand (TOD) - A recently developed test to measure the organic content of wastewater in which the organics are converted to stable end products in a platinum-catalyzed combustion chamber. The test can be performed quickly, and results have been correlated with the COD in certain locations.

4. Total organic carbon (TOC) - Still another means of measuring the organic matter present in water which has found increasing use in recent times. The test is especially applicable to small concentrations of organic matter.

5. Chloride - One of the major anions in water and sewage. The concentration in sewage may be increased by some industrial wastes, by runoff from streets and highways where salt is used to control ice formation, salt water intrusion in tidal areas, etc. A high chloride content is injurious to vehicles and highway structures, and may contaminate water supplies near the highway.

6. Nitrogen Series - A product of microbiologic activity, is an indicator of sewage pollution, or pollution resulting from fertilizers, automobile exhausts, or other sources. Its presence may require additional amounts of chlorine, or introduction of a nitrogen fixation process, in order to produce a free chlorine residual in control of bacteria.

7. pH - The logarithm of the reciprocal of hydrogen ion activity. State regulations often prescribe pH limits for effluents from industrial waste treatment plants. Provides a control in chemical and biological treatment processes for wastewater.

8. Solids (Total, Suspended, Volatile, and Settleable) - Usually represent a large fraction of the pollutional load in combined sewage. Inorganic sediments, in a physical sense, are major pollutants, but also serve as the transporting or catalytic agents that may either expand or reduce the severity of other forms of pollution (6).

9. Oil and Grease - Commonly found in sanitary sewage, but also appear in industrial wastes as a result of various industrial processes. Present a serious problem of removal in wastewater treatment facilities.

10. Bacterial Indicators (Total Coliform, Fecal Coliform, Fecal Streptococcus) - Indicate the level of bacterial contamination.

Where more exotic wastes are combined with stormwater and sanitary sewage, additional treatment facilities may be required for the removal of industrial byproducts and nutrients such as cyanide, fluoride, metals, pesticides, nitrogen, phosphorus, sulfate and sulfide. For planning and design of such treatment facilities, additional analyses are required in accordance with the pollutant material expected in the wastewater. This may, in turn, require significant expansion of the sampling program.

Sampling and analyses of wastewater are necessary to the satisfactory operation of treatment plants. Pollutants in the incoming storm sewer or combined sewer are compared with those in the effluent from the treatment plant to determine the effectiveness of the treatment process. Additionally, sampling of the receiving stream before and after treatment/control system installation indicates the benefits gained from the installation. Knowledge of the concentration of pollutants entering the plant can be used also to make adjustments to the treatment process as required. Continuous monitoring of the stream below the treatment/control facility is important to facility operation. Depending on the type or types of treatment process used, the number of parameters required for sampling and analyses is usually less than those required for planning and design. For example, where treatment consists only of sedimentation and chlorination, analyses for oxygen demand, suspended solids, bacterial indicators, and for chlorine residual may be sufficient. If chemicals are used to assist the sedimentation process, determination of pH may be needed. The sampling program can be determined largely in accordance with previous experience and knowledge of the pollutants found.

Sampling programs should start long before installation of combined sewer overflow and stormwater treatment/control facilities to establish the objectives of the facilities and to provide necessary design and operation criteria. A much longer time period for sampling may be required than anticipated because of the need to sample during periods of storm runoff, which may be few in drought years.

In some cases, the availability of historical quality data may provide a basis for prediction of future character for planning and design purposes. Dependence on such predicted data is not sufficient, and collection of current data is required to verify predictions and, later, to measure facility effectiveness.

Programs of sampling and analyses of wastewater in storm and/or combined sewers are frequently used for the enforcement of water quality standards or objectives. Such programs provide information leading to the source of various types of pollution. Often, the wastewater is continually monitored to check on compliance with pollution control laws and regulations. The range of different parameters to be measured for these purposes is continually expanding with the development of new processes. There appears to be no limit to future analytical requirements.

SECTION V

DESIRABLE EQUIPMENT CHARACTERISTICS

Having reviewed some of the vagaries of the storm and combined sewer sampling problem in the preceding sections, it is intuitively obvious that a single piece of equipment cannot exist that is ideal for all sampling programs in all storm and combined sewer flows of interest. One can, however, set down some general requirements for sampling equipment that is to be used in the storm or combined sewer application.

EQUIPMENT REQUIREMENTS

The success of an automatic sampler in gathering a representative sample starts with the design of the sampler intake. This obviously will be dependent upon conditions at the particular site where the sample is to be extracted. If one is fortunate enough to have a situation where the sewer flow is homogeneous with respect to the parameters being sampled, then a simple single point of extraction for the sample will be adequate. In the more typical case, however, there is a spatial variation in the concentration of the particular constituent that is to be examined as part of a sampling program, and then the sampling intake must be designed so that the sample which is gathered will be nearly representative of the actual flow. Several different designs have been utilized in an attempt to meet this objective. However, none can be considered as ideal or universally applicable. In a rather comprehensive study reported in (7), the characteristics of the sampler orifice geometry were examined with particular regard to the ability of the sampler to gather a representative sample of suspended solids. Among parameters varied were size of orifice, shape of orifice and intake velocity. All orifices were located in a vertical plate forming part of the wall of the test section of the flume which was used for this study. The sample flow was therefore extracted at right angles to the stream flow. The major conclusion that was reached by the investigators was that, as far as suspended solids were concerned, the geometry of the orifice at most played a secondary role and that the most representative samples were obtained when the sampler intake tube velocity was equal to the free stream velocity. In situations where flow velocity gradients are strongly present, this observation must be taken into account in the design of a proper sampler intake.

The automatic sampler must be capable of lifting the sample to a sufficient height to allow its utilization over a rather wide range of operating heads. It would appear that a minimum sample lift of 3 meters or so is almost mandatory in order to give a fairly wide range of applicability. It is also important that the sample size not be a function of the sample lift; that is, the sample size should not become significantly less as the sample lift increases.

The sample line size must be large enough to give assurances that there will be no plugging or clogging anywhere within the sampling train. However, the line size must also be small enough so that complete transport of suspended solids is assured. Obviously, the velocities in any vertical section of the sampling train must well exceed the settling velocity of the maximum size particle that is to be sampled. Thus, the sample flow rate and line size are connected and must be approached together from design considerations.

The sample capacity that is designed into the piece of equipment will depend upon the subsequent analyses that the sample is to be subjected to and the volumetric requirements for conducting these analyses. However, in general, it is desirable to have a fairly large quantity of material on hand, it being safer to err on the side of collecting too much rather than too little. For discrete samples, 500 mℓ is frequently the bare minimum, and a liter or more is often desirable. For composite samples, at least 4 liters and preferably more should be collected.

The controls on the automatic sampler should allow some degree of freedom in the operation and utilization of the particular piece of equipment. A built-in timer is desirable to allow preprogrammed operation of the equipment. Such operation would be particularly useful, for example, in characterizing the buildup of pollutants in the early stages of storm runoff. However, the equipment should also be capable of taking signals from some flow measuring device so that flow proportional operation can be realized. It is also desirable that the equipment be able to start up automatically upon signal from some external device that might indicate the onset of storm flow phenomena such as an external rain gauge, flow height gauge, etc. Flexibility in operation is very desirable.

A power source will be required for any automatic sampler. It may take the form of a battery pack or clock type spring motor that is integral to the sampler itself. It may be pressurized gas, air pressurized from an external source, or electrical power, depending upon the availability at the site.

In addition to being able to gather a representative sample from the flow, the sampling equipment must also be capable of transporting the sample without pre-contamination or cross-contamination from earlier samples or aliquots and of storing the gathered sample in some suitable way. As was noted in section IV, chemical preservation is required for certain parameters that may be subject to later analyses, but refrigeration of the sample is also required and is stated as the best single means of preservation.

DESIRABLE FEATURES

In addition to the foregoing requirements of automatic sampling equipment, there are also certain desirable features which will enhance the utility and value of the equipment. For example, the design should be such that maintenance and troubleshooting are relatively simple tasks. Spare parts should be readily available and reasonably priced. The equipment design should be such that the unit has maximum inherent reliability. As a general rule, complexity in design should be avoided even at the sacrifice of a certain degree of flexibility of operation. A reliable unit that gathers a reasonably representative sample most of the time is much more desirable than an extremely sophisticated complex unit that gathers a very representative sample 10 percent of the time, the other 90 percent of the time being spent undergoing some form of repair due to a malfunction associated with its complexity.

It is also desirable that the cost of the equipment be as low as practical both in terms of acquisition as well as operational and maintenance costs. For example, a piece of equipment that requires 100 man-hours to clean after each 24 hours of operation is very undesirable. It is also desirable that the unit be capable of unattended operation and remaining in a standby condition for extended periods of time.

The sampler should be of sturdy construction with a minimum of parts exposed to the sewage or to the highly humid, corrosive atmosphere associated directly with the sewer. It should not be subject to corrosion or the possiblity of sample contamination due to its materials of construction. The sample containers should be capable of being easily removed and cleaned; preferably they should be disposable.

For portable automatic wastewater samplers, the list of desirable features is even longer. In a recent EPA publication (8), a number of features of an "ideal" portable sampler are given based upon sampler comparison studies and over 90,000 hours of field experience. Included were:

- Capability for AC/DC operation with adequate battery energy storage for 120-hour operation at 1-hour sampling intervals.
- Suitable for suspension in a standard manhole and still provide access for inspection and sample removal.
- Total weight including batteries under 18 kilograms (40 pounds).
- Sample collection interval adjustable from 10 minutes to 4 hours.
- Capability for collecting both simple and flow-proportional composite samples.
- Capable of collecting a single 9.5ℓ (2.5 gal) sample and/or collecting 500 mℓ (0.13 gal) discrete samples in a minimum of 24 containers.
- Capability for multiplexing repeated aliquots into discrete bottles (i.e., sequential composite).
- Intake hose liquid velocity adjustable from 0.61 to 3 m/sec (2.0 to 10 fps) with dial setting.
- Minimum lift of 6.1 meters (20 feet).
- Explosion proof.
- Watertight exterior case to protect components in the event of rain or submersion.
- Exterior case capable of being locked and with lugs for attaching steel cable to prevent tampering and provide some security.
- No metal parts in contact with waste source or samples.

- An integral sample container compartment capable of maintaining samples at 4°C (39°F) for a period of 24 hours at ambient temperatures up to 38°C (100°F).

- With the exception of the intake hose, capable of operating in a temperature range between -10 to 40°C (14 to 104°F).

- Purge cycle before and after each collection interval and sensing mechanism to purge in event of plugging during sample collection and then collect complete sample.

- Capable of being repaired in the field.

PROBLEM AREAS

The sampler by its design must have a maximum probability of successful operation in the very hostile storm and combined sewer environment. It should offer every reasonable protection against obstruction or clogging of the sampling ports and, within the sampler itself, of the sampling train. It is in a very vulnerable position if it offers any significant obstruction to the flow because of the large debris which are sometimes found in such waters. The unit must be capable of operation under the full range of flow conditions which are peculiar to storm and combined sewers and this operation should be unimpeded by the movement of solids within the fluid flow. If the unit is to be designed for operation in a manhole, it almost certainly should be capable of total immersion or flooding during adverse storm conditions which very frequently cause surcharging in many manhole areas. It is also necessary that the unit be able to withstand and operate under freezing ambient conditions, and that it be able to withstand the high flow velocities and the associated high momentums found in storm and combined sewer flows.

Probably one of the most significant problem areas lies in the attempt to gather a sample that is representative of low as well as high specific gravity suspended solids. The different momentum characteristics call for differing approaches in sampler intake design and in intake velocities. Another problem area arises in a sampling program where it is desirable to sample floatable solids and materials such as oils and greases as well as very coarse bottom solids and bed load proper.

For samples which are to be analyzed for constituents which require chemical fixing soon after the sample is collected, there are other problems. Although it is true that the required amount of fixing agent could be placed in the sample container prior to placing it in the field, for composite samples in particular, where the eventual total sample is built up of smaller aliquots gathered over an extended period of time, the initial high concentrations of the fixing agent as it becomes mixed with the early aliquots may well be such as to render the entire sample unsuitable for its intended purpose.

The precision of the analyses that the sample is to be subjected to should also be kept in mind by the designer of the equipment. For example, in (4) it is noted that 86 analysts in 58 laboratories analyzed natural water samples plus an exact increment of biodegradable organic compounds. At a mean value of 2.1 and 175 milligrams per liter BOD, the standard deviation was plus or minus 0.7 and 26 milligrams per liter, respectively. This points out again the need for the designer to look at the left as well as the right of the decimal point.

Finally, the materials of construction used in the sampling train may well create problems. Absorption of certain pollutants by these materials (especially those of the sample container with its longer contact time) may well result in a non-representative sample. The problem is compounded by the fact that no single material is ideally suited for use with all possible pollutants.

SECTION VI

REVIEW OF COMMERCIALLY AVAILABLE AUTOMATIC SAMPLERS

INTRODUCTION

Although some types of automatic liquid sampling equipment have been available commercially for some time, project engineers continue to design custom sampling units for their particular projects due to a lack of commercial availability of suitable equipment. In the last few years, however, there has been a proliferation of commercial sampling equipment designed for various applications. In the present survey, after a preliminary screening, over 40 prospective sampler manufacturers were contacted. Although a few of these companies were no longer in business, it was much more typical that new companies were being formed and existing companies were adding automatic sampling equipment to their product lines. In addition to their standard product lines, most manufacturers of automatic sampling equipment provide special adaptations of their equipment or custom designs to meet unique requirements of certain projects. Some designs which began in this way have become standard products, and this can be expected to continue.

The products themselves are rapidly changing also. Not only are improvements being made as field experience is gathered with new designs, but attention is also being paid to certain areas that have heretofore been largely ignored. For example, one company is introducing sampling probes that allow gathering oil or various other liquids from the flow surface; solid-state electronics are being used more and more in sampler control subsystems; new-type batteries are offering extended life between charges and less weight; and so on. Table 3 lists the names and addresses of 32 manufacturers who are known to offer standard lines of automatic wastewater sampling equipment. In view of the burgeoning nature of this product area, it is inevitable that some omissions have been made. Obviously, it would be presumptive to state that this survey is complete in every detail. Any manufacturers that have possibly been overlooked or that have (or plan to) introduce new models or changes to existing ones are urged to communicate details about their equipment to the USEPA Project Officer and/or the authors, at the addresses indicated on the title page of this report, so that they can be included in future updates of this work.

In order to facilitate the reader's comparison of the 71 descriptions that are presented covering over 200 models of

TABLE 3. AUTOMATIC WASTEWATER SAMPLER MANUFACTURERS

Bestel-Dean Limited
92 Worsley Road North,
Worsley
Manchester, England M28 5QW

BIF Sanitrol
P.O. Box 41
Largo, Florida 33546

Brailsford and Company, Inc.
Milton Road
Rye, New York 10580

Brandywine Valley Sales Co.
20 East Main Street
Honey Brook, PA 19344

Chicago Pump Division
FMC Corporation
622 Diversey Parkway
Chicago, Illinois 60614

Collins Products Co.
P.O. Box 382
Livingston, Texas 77351

Environmental Marketing
Associates
3331 Northwest Elmwood Dr.
Corvallis, Oregon 97330

ETS Products
12161 Lackland Road
St. Louis, Missouri 63141

Fluid Kinetics, Inc.
3120 Production Drive
Fairfield, Ohio 45014

Horizon Ecology Company
7435 North Oak Park Drive
Chicago, Illinois 60648

Hydra-Numatic Sales Co.
65 Hudson Street
Hackensack, NJ 07602

Hydraguard Automatic
Samplers
850 Kees Street
Lebanon, Oregon 97355

Instrumentation Specialties
Company
Environmental Division
P.O. Box 5347
Lincoln, Nebraska 68505

Kent Cambridge Instrument
Company
73 Spring Street
Ossining, New York 10562

Lakeside Equipment Corp.
1022 East Devon Avenue
Bartlett, Illinois 60103

Manning Environmental Corp.
120 DuBois Street
P.O. Box 1356
Santa Cruz, California 98061

Markland Specialty Eng. Ltd.
Box 145
Etobicoke, Ontario (Canada)

Nalco Chemical Company
180 N. Michigan Avenue
Chicago, Illinois 60601

Nappe Corporation
Croton Falls Industrial Complex
Route 22
Croton Falls, New York 10519

N-Con Systems Company
308 Main Street
New Rochelle, New York 10801

Paul Noascono Company
805 Illinois Avenue
Collinsville, Illinois 62234

TABLE 3. AUTOMATIC WASTEWATER SAMPLER MANUFACTURERS (Cont'd)

Peri Pump Company, Ltd.
180 Clark Drive
Kenmore, New York 14223

Phipps and Bird, Inc.
303 South 6th Street
Richmond, Virginia 23205

Protech, Inc.
Roberts Lane
Malvern, PA 19355

Quality Control Equipment
Company
P.O. Box 2706
Des Moines, Iowa 50315

Rice Barton Corporation
P.O. Box 1086
Worcester, MA 01601

Sigmamotor, Inc.
14 Elizabeth Street
Middleport, New York 14105

Sirco Controls Company
8815 Selkirk Street
Vancouver, B. C. (Canada)

Sonford Products Corporation
100 East Broadway, Box B
St. Paul Park, MN 55071

Testing Machines, Inc.
400 Bayview Avenue
Amityville, New York 11701

Tri-Aid Sciences, Inc.
161 Norris Drive
Rochester, New York 14610

Williams Instrument Co., Inc.
P.O. Box 4365, North Annex
San Fernando, California 91342

automatic samplers, a common format has been designed. A few words about the headings of this format are in order.

Designation: Identifies the particular sampler model that is being considered. In some instances several models are described under the same general heading. This occurs when there does not appear to be a fundamental difference in the basic principles of operation, but rather, the manufacturer has chosen to give separate designations based upon the addition of certain features such as refrigeration, a weatherproof case, etc.

Manufacturer: Lists the company that supplies the particular model in question, its address, and its telephone number.

Sampler Intake: Describes the part of the sampler that actually extracts fluid from the stream being sampled. It may be, for example, a supplied custom designed intake probe, a dipping bucket or scoop, etc. However, many of the samplers do not provide any form of intake other than the end of a tube through which a sample is to be transported to the equipment.

Gathering Method: Addresses the method for gathering the sample and transporting it to its container. Three basic categories are identified: Mechanical, where dippers, scoops, etc., are utilized; Suction Lift, employing either evacuated vessels, vacuum pump, or mechanical pump; and Forced Flow, utilizing pneumatic ejection, a submerged pump, etc.

Sample Lift: Addresses the maximum practical vertical lift that the particular piece of equipment is capable of in operation.

Line Size: Describes the minimum line diameter of the sampling train wherever it may occur in the particular piece of equipment. Due to the presence of tube fittings, screens, valves, etc., in some designs, it does not necessarily represent maximum particle size.

Sample Flow Rate: Gives the flow rate of the sample as it is being transported within the sampling train of the piece of equipment in question.

Sample Capacity: Addresses the size of the sample that is being collected. In the case of composite samplers, the aliquot size is also given.

Controls: Addresses those controls within the sampler that can be utilized to vary its method of operation. For example, built-in timers, inputs from external flowmeters, etc.

Power Source: Gives power source or sources that may be utilized to operate the equipment.

Sample Refrigerator: Addresses the type of cooling that may be available to provide protection to collected samples.

Construction Materials: Primary attention here has been devoted to the sampling train proper, although certain other materials such as case construction are also noted.

Basic Dimensions: The overall package is described here in order to give the reader a general feel for the size of the unit. For those units which might be considered portable, a weight is also given. For units that are designed for fixed installations only, this fact is also noted.

Base Price: The base price of the unit is given here. Certain options or accessories that may be of general interest are also included with their prices. Prices given are generally those quoted for January 1975 delivery. Because of the economic conditions prevalent at that time, however, many manufacturers recommend checking with them, even for estimating or planning purposes.

General Comments: Here any additional comments that are felt to be pertinent to the particular piece of equipment in question are given. This includes any additional descriptions that are felt necessary in order to understand better the operating principles that are involved. Also included are certain performance claims that may be made by the manufacturer.

An overall matrix, which summarizes the detailed descriptions to facilitate comparisons, is presented in Table 4. There are several column headings for each sampler model (or class of models). "Gathering Method" identifies the actual method used (mechanical, forced flow, suction lift) and type (peristaltic-, vacuum-, centrifugal-pump, etc.). Depending upon the gathering method employed, the sample flow rate may vary while a sample is being taken, vary with parameters such as lift, etc. Therefore, the "Flow Rate" column typically lists the upper end of the range for a particular piece of equipment and values significantly less may be encountered in a field application. "Lift" indicates the maximum vertical distance that is allowed between the sampler intake and the remainder of the unit (or at least its pump in the case of suction lift devices).

"Line Size" indicates the minimum line diameter of the sampling train. "Sample Type" indicates which type or types of sample, as identified in section IV, the unit (or series) is capable of gathering. Not all types can necessarily be taken by all units in a given model class; e.g., an optional controller may be required to enable taking a TvVc type sample, etc. The "Installation" column is used to indicate if the manufacturer considers the unit to be portable or if it is primarily intended for a fixed installation. "Cost Range" indicates either the approximate cost for a typical unit or the lowest price for a basic model and a higher price reflecting the addition of options (solid state controller, battery,

TABLE 4. SAMPLER CHARACTERISTIC SUMMARY MATRIX

Sampler	Gathering Method	Flow Rate (ml/min)	Lift (m)	Line Size (mm)	Sample Type	Instal-lation	Cost Range ($)	Power
Bestel-Dean Mk II	S-Watson-Marlow	690	6.1	6.4	D, TcVc, TvVc	Portable	Unk.	AC/DC
Bestel-Dean Crude	S-screw type	Unk.	6.1	19.1	D, TcVc, TvVc	Portable	Unk.	AC
BIF 41	M-cup on chain	NA	4.9	25.4	TcVc, TvVc	Fixed	~1,000	AC
Brailsford DC-F & FP	S-piston type	10	2	4.8	Continuous	Portable	296-373	DC
Brailsford EVS	S-vacuum pump	5	3.7	4.8	TcVc, TvVc	Portable	520-672	AC/DC
Brailsford DU-2	S-piston type	10	<2	4.8	TcVc, TvVc	Portable	373	DC
BVS PP-100	F-pneumatic	*	85	3.2	TcVc, TvVc	Portable	853-1,525	AC/DC
BVS PP-400	F-submersible pump	7,600	9.8	12.7	TcVc, TvVc	Portable	1,500-2,510	AC/DC
BVS SE-800	F-submersible pump	7,600	9.8	12.7	D, TcVc, TvVc	Fixed	5,650	AC
BVS PPE-400	F-pneumatic	*	85	3.2	TcVc, TvVc	P or F	1,450-3,350	AC/DC
Chicago Pump	user supplied	~133,000	NA	25.4	TcVc, TvVc	Fixed	2,600-3,200	AC
Collins 42	user supplied	>3,765	NA	2.4	TcVc, TvVc	P or F	985-2,478	AC
Collins 40	user supplied	~5,000	NA	2.4	TcVc, TvVc	P or F	935-2,328	AC
EMA 200	F-piston type	Unk.	<1	9.5	TcVc, TvVc	Portable	199-456	AC/DC
ETS FS-4	S-peristaltic	~20	8.8	6.4	Continuous	Portable	1,095-up	AC
Horizon S7570	S-peristaltic	100	9.1	0.8	Grab	Portable	~410	AC/DC
Horizon S7576	S-peristaltic	100	9.1	0.8	TcVc	Portable	~220	AC
Horizon S7578	S-peristaltic	100	9.1	0.8	Continuous, TcVc	Portable	595	DC
Hydraguard HP	F-pneumatic	*	<9	6.4	TcVv	Portable	246-541	Air
Hydraguard A	F-pneumatic	*	<9	6.4	TvVc	Portable	286-666	Air & AC
Hydr-Numatic	S-centrifugal	5,700	4.6	6.4	TcVc, TvVc	Portable	1,600	AC
ISCO 1392	S-peristaltic	1,500	7.9	6.4	D, TcVc, TvVc, S	Portable	1,095-1,498	AC/DC
ISCO 1480	S-peristaltic	NA	7.9	6.4	TcVc, TvVc	Portable	645-1,020	AC/DC
ISCO 1580	S-peristaltic	1,400	7.9	6.4	TcVc, TvVc	Portable	750-1,130	AC/DC
Kent SSA	S-peristaltic	150	4.9	6.4	Discrete	Portable	1,240	AC/DC
Kent SSB	S-peristaltic	200	4.0	6.4	D, TcVc, TvVc, S	Fixed	2,354	AC
Kent SSC	S-screw type	33,000	5.0	25.4	D, TcVc, TvVc, S	Fixed	2,354	AC
Lakeside T-2	M-scoop	NA	0	12.7	TcVv	Fixed	~700-up	AC
Manning S-4000	S-vacuum pump	3,800	6.7	9.5	D, S	Portable	1,290	DC
Markland 1301	F-pneumatic	*	18.3	6.4	TcVc, TvVc	Portable	1,095-1,350	Air & DC
Markland 101 & 102	F-pneumatic	*	18.3	6.4	D, TcVc	Fixed	594-2,189	Air & DC
Markland 104T	F-pneumatic	*	18.3	6.4	D, TcVc, TvVc	Fixed	1,094-2,644	Air & AC
Nalco S-100	F-submersible pump	28,400	7.6	12.7	TcVc, TvVc	Portable	Unk.	AC
Nappe Porta-Positer	S-flexible impeller	11,400	1.8	6.4	TcVc	Portable	225-285	AC/DC
Nappe Series 46	S-flexible impeller	13,200	4.6	9.5	TcVc, TvVc	Fixed	1,100-1,800	AC
Noascono Shift	S-peristaltic	8	9.1	4.8	Continuous	Portable	Unk.	AC
N-Con Surveyor II	S-flexible impeller	20,000	1.8	6.4	TcVc, TvVc	Portable	290-590	AC
N-Con Scout II	S-peristaltic	150	5.5	6.4	TcVc, TvVc	Portable	575-935	AC/DC
N-Con Sentry 500	S-peristaltic	150	5.5	6.4	Sequential	Portable	1,125-1,205	AC/DC
N-Con Trebler	M-scoop	NA	0	12.7	TcVv	Fixed	1,050-1,350	AC
N-Con Sentinel	user supplied	63,000	NA	25.4	TcVc, TvVc	Fixed	~2,600	AC

TABLE 4. SAMPLER CHARACTERISTIC SUMMARY MATRIX (Cont'd)

Sampler	Gathering Method	Flow Rate (ml/min)	Life (m)	Line Size (mm)	Sample Type	Instal-lation	Cost Range ($)	Power
Peri 704	S-peristaltic	160	7.6	6.4	TcVc	Portable	Unk.	DC
Phipp. and Bird	M-cup on chain	NA	18.3	NA	TcVc, TvVc	Fixed	~1,000-up	AC
ProTech CG-110	F-pneumatic	1,000	9.1	3.2	TcVc	Portable	485	-
ProTech CG-125	F-pneumatic	1,000	9.1	3.2	TcVc	Portable	695-1,205	-/AC
ProTech CG-125FP	F-pneumatic	1,000	9.1	3.2	TcVc, TvVc	Portable	925-1,610	AC/DC
ProTech CEG-200	F-pneumatic	1,000	16.8	3.2	TcVc, TvVc	P or F	1,345-2,445	Air/AC
ProTech CEL-300	F-submersible pump	~6,000	9.1	12.7	TcVc, TvVc	P or F	1,495-2,750	AC
ProTech DEL-4005	F-submersible pump	~6,000	9.1	12.7	Discrete	Fixed	3,995-4,765	AC
QCEC CVE	S-vacuum pump	3,000	6.1	6.4	TcVc, TvVc	Portable	570-1,030	AC/DC
QCEC CVE II	S-vacuum pump	3,000	6.1	6.4	TcVc, TvVc	Portable	~1,000-up	AC/DC
QCEC L	M-cup on chain	NA	18.3	NA	TcVc, TvVc	Fixed	~1,000-up	AC
Rice Barton	S-vacuum pump	Unk.	3.7	25.4	TcVc	Fixed	Unk.	AC
SERCO NW-3	S-evacuated jars	Varies	~3	6.4	Discrete	Portable	~1,000	-
SERCO TC-2	user supplied	42,000	NA	~19	TcVc, TvVc	Fixed	~2,500	Air & AC
Sigmamotor WA-1	S-peristaltic	60	6.7	3.2	TcVc	Portable	430-730	AC/DC
Sigmamotor WAP-2	S-peristaltic	60	6.7	3.2	TcVc, TvVc	Portable	650-870	AC/DC
Sigmamotor WM-3-24	S-peristaltic	60	6.7	3.2	Discrete	Portable	975-1,525	AC/DC
Sigmamotor WA-5	S-peristaltic	80	5.5	6.4	TcVc	Portable	750-990	AC/DC
Sigmamotor WAP-5	S-peristaltic	80	5.5	6.4	TcVc, TvVc	Portable	850-1,215	AC/DC
Sigmamotor WM-5-24	S-peristaltic	80	5.5	6.4	Discrete	Portable	1,225-1,775	AC/DC
Sirco B/ST-VS	S-vacuum pump	12,000	6.7	9.5	TcVc, TvVc	P or F	1,900-3,000	AC/DC
Sirco B/IE-VS	M-cup on cable	NA	61	9.5	TcVc, TvVc	Fixed	1,500-3,000	AC
Sirco B/DP-VS	user supplied	-	NA	9.5	TcVc, TvVc	P or F	1,600-3,000	AC/DC
Sirco MK-VS	S-vacuum pump	6,000	6.7	9.5	D, TcVc, TvVc, S	Portable	~1,300-up	AC/DC
Sonford HG-4	M-dipper	NA	0.5	19.0	TcVc, TvVc	Portable	325-495	AC/DC
Streamgard DA-24S1	user supplied	NA	NA	6.4	Discrete	Portable	775	-
THI Fluid Stream	F-pneumatic	*	7.6	12.7	TcVc	Fixed	~800	Air & AC
THI NA 3B (Hants)	S-evacuated jars	Varies	~3	3.2	Discrete	Portable	~700-up	-
Tri-Aid	S-peristaltic	500	7.5	9.5	TcVc, TvVc	P or F	650-985	AC
Williams Oscillamatic	S-diaphragm type	60	3.6	6.4	TcVc	P or F	438	-

Legend:
M - Mechanical
F - Forced Flow
S - Suction Lift
* - Depends on pressure and lift
NA - Not Applicable
Unk - Unknown at time of writing

refrigerator, etc.) that might enhance the utility of the device. Finally, the "Power" column is used to indicate whether line current (AC), battery (DC), or other forms of power (e.g., air pressure) are required for the unit to operate.

In general, the commercially available automatic samplers have been designed for a particular type of application. In the present work, however, they are being considered for application in a storm or combined sewer setting. Because of the vagaries of such an application as outlined in Sections III and IV of this report, it is altogether possible that a particular unit may be quite well suited for one particular application and totally unsuitable for use in another. It is not the intention of this report to endorse any particular piece of equipment. Rather, they are being compared and evaluated for their suitability in general in a storm or combined sewer application. This evaluation takes the form of 12 points which are addressed for each model sampler that has been considered. They are as follows:

1. Obstruction or clogging of sampling ports, tubes, and pumps.

2. Obstruction of flow.

3. Operation under the full range of flow conditions peculiar to storm and combined sewers.

4. Operation unimpeded by the movement of solids such as sand, gravel and debris within the fluid flow; including durability.

5. Operation automatic (during storm conditions), unattended, self-cleaning.

6. Flexibility of operation allowed by control system.

7. Collection of samples of floatable materials, oils and grease, as well as coarser bottom solids.

8. Storage, maintenance and protection of collected samples from damage and deterioration as well as the sample train and containers from precontamination.

9. Amenability to installation and operation in confined and moisture laden places such as sewer manholes.

10. Ability to withstand total immersion or flooding during adverse flow conditions.

11. Ability to withstand and operate under freezing ambient conditions.

12. Ability to sample over a wide range of operating head conditions.

DESCRIPTIVE FORMS AND EVALUATIONS

The descriptive forms and evaluations, as discussed above, are presented in the following pages for various commercially available automatic samplers. The arrangement is alphabetical, and an index is provided on pages x through xii.

Designation:	BESTEL-DEAN MARK II
Manufacturer:	Bestel-Dean Limited 92 Worsley Road North, Worsley Manchester, England M28 5QW Phone FARNWORTH 75727
Sampler Intake:	End of 6.10m (20 ft) long suction tube installed to suit by user.
Gathering Method:	Suction lift (from a Watson-Marlow type MHRK fixed speed flow inducer).
Sample Lift:	6.10m (20 ft) maximum lift.
Line Size:	0.64 cm (1/4") I.D.
Sample Flow Rate:	Approximately 690 mℓ per minute.
Sample Capacity:	Composites adjustable size aliquots from 5 mℓ to 2 liters in an external user-supplied sample container. With optional portable bottler, the unit takes 24-250 mℓ discrete samples.
Controls:	Sample timer which controls sample volume is adjustable from 1 to 4 minutes, interval timer from 5 to 60 minutes, and purge timer from 1 to 4 minutes, all being controlled by a solid state unit having three adjustable timers. The sampling cycle can be initiated by a test button, by the internal pre-set timer, or by remote pulse from an external flowmeter.
Power Source:	115/230 VAC or 12 VDC.
Sample Refrigerator:	None.
Construction Materials:	Casing and base are reinforced fiberglass, tubing is neoprene.

Basic Dimensions:	61 x 37 x 28 cm (24x14.5x11 in.) in operational state; weight is 10.65 kgs (23.5 lbs) less battery; portable unit. Bottler is 30.5 cm (12 in.) H x 38 cm (15 in.) dia.
Base Price:	Unknown.
General Comments:	Unit is also designed to work as a discrete sampler when used in conjunction with the Bestel-Dean portable bottler unit. All controls are front panel, solid state. Unit is fully portable. Battery unit and sample container must be supplied by user.

Bestel-Dean Mark II Evaluation

1. Sampler should be relatively free from clogging.

2. Obstruction of flow will depend upon user mounting of intake line.

3. Unit should operate reasonably well over entire range of flow conditions.

4. Movement of solids should not affect operation adversely.

5. No automatic starter. At start of each cycle, pump operates in reverse to clear line of previous sample to help minimize cross contamination and offer a sort of self cleaning.

6. Unit can take fixed-time interval samples or flow proportional composite samples or discrete samples with optional bottler.

7. Unit does not appear suitable for collecting either floatables or coarser bottom solids.

8. No sample collector provided. Unit can be connected to the optional Bestel-Dean bottler unit. Cross-contamination should be small.

9. Unit should be able to operate in a manhole environment.

10. Unit cannot withstand total immersion.

11. Unit does not appear suited for operation in freezing ambients.

12. Maximum lift of 6.1m (20 ft) does not place great operating restriction on unit.

Designation:	BESTEL-DEAN CRUDE SEWAGE SAMPLER
Manufacturer:	Bestel-Dean Limited 92 Worsley Road North, Worsley Manchester, England, M28 5QW Phone FARNWORTH 75727
Sampler Intake:	End of 6.10m (20 ft) long suction tube fitted with a special deflector and strainer and installed to suit by user.
Gathering Method:	Suction lift from progressive cavity screw-type pump.
Sample Lift:	6.10m (20 ft) maximum lift.
Line Size:	1.9 cm (3/4 in.) I.D.
Sample Flow Rate:	Unknown.
Sample Capacity:	Collects either 24 discrete 250 mℓ samples or a 25 liter composite made up of 250 mℓ aliquots.
Controls:	Cycle timer is adjustable for settings from 0-4-1/2 hours with minimum time setting of 12 minutes. Purge timer can be set for up to 13-1/2 minutes with a minimum of 30 seconds. May also be paced by an external flowmeter.
Power Source:	240 VAC
Sample Refrigerator:	None.
Construction Materials:	The pipework system with valves and sample container are plastic. Casing is weatherproof sheet steel with an epoxy resin coating. Pump rotor is stainless steel and stator is nitrile rubber.
Basic Dimensions:	76 x 76 x 107 cm (30x30x42 in.). Designed for fixed installation.

Base Price: Unknown.

General Comments: Discharge line should be located downstream from suction line to prevent possible contamination of new sample. On installations where flow integrating equipment does not have available a suitable pulsing contact, a load-free impulse device which can be adapted to any flowmeter is optionally available. A solid state electronic power unit is available as an option for use with the impulse unit. Standard equipment is set to take a 250 mℓ volume aliquot. Other volumes, between 250 mℓ and 100 mℓ, can be supplied by special order. Thermostat for heater is optionally available.

Bestel-Dean Crude Sewage Sampler Evaluation

1. The deflector and strainer will help prevent blockage, and unit does not appear at all vulnerable to clogging due to large I.D. piping and choke-free valve design.

2. Obstruction of flow will depend upon user mounting of intake line.

3. Unit should operate reasonably well under all flow conditions.

4. Movement of solids within the fluid flow should not affect operation adversely.

5. No automatic starter; purging action before each sample should clear the sampler of any fluid left from the previous sample.

6. Unit can take either fixed time interval samples paced by a built-in timer or flow proportional samples paced by an external flowmeter.

7. Unit does not appear suitable for collecting either floatable or coarser bottom solids.

8. Unit offers reasonable sample protection, but offers no refrigeration.

9. Unit is intended for permanent outdoor installation, but is not designed for confined space or manhole operation.

10. Unit cannot withstand total immersion.

11. An electrical heater is mounted inside the case and can be manually switched on or thermostatically controlled for operation during freezing conditions.

12. Maximum lift of 6.10m (20 ft) does not place a severe operating restraint on unit.

Designation:	BIF SANITROL FLOW-RATIO MODEL 41
Manufacturer:	BIF Sanitrol P.O. Box 41 Largo, Florida 33540 Phone (813) 584-2157
Sampler Intake:	Dipping bucket
Gathering Method:	Mechanical; dipper on sprocket-chain drive.
Sample Lift:	41 cm (16 in.) to 4.9m (16 ft)
Line Size	2.5 cm (1 in.) O.D. tube connects collection funnel to sample container
Sample Flow Rate:	Not applicable
Sample Capacity:	Dipping bucket holds 30 mℓ (1 oz); user supplies sample composite container to suit.
Controls:	Sampling cycle can either be started at fixed, selected intervals from a built-in timer (15, 7.5, 3.75, or 1.88 minutes) or in response to signals from an external flowmeter.
Power Source:	115 VAC
Sample Refrigerator:	Separate automatic refrigerated sample compartment with two 3.8ℓ (1 gal) jugs available.
Construction Materials:	Dipper and funnel are stainless steel; sprockets and chain are stainless steel; enclosure is fiberglass.
Basic Dimensions:	Upper portion is approximately 24 x 24 x 20 cm (9x9x8 in.); lower portion is 24 x 10 cm (9x4 in.); fixed installation.
Base Price:	$545 with 41 cm (16 in.) mild steel chain plus $40 per foot (0.3m) for additional length. $595 with 16" stainless steel chain plus $50 per foot (0.3m) for additional length.

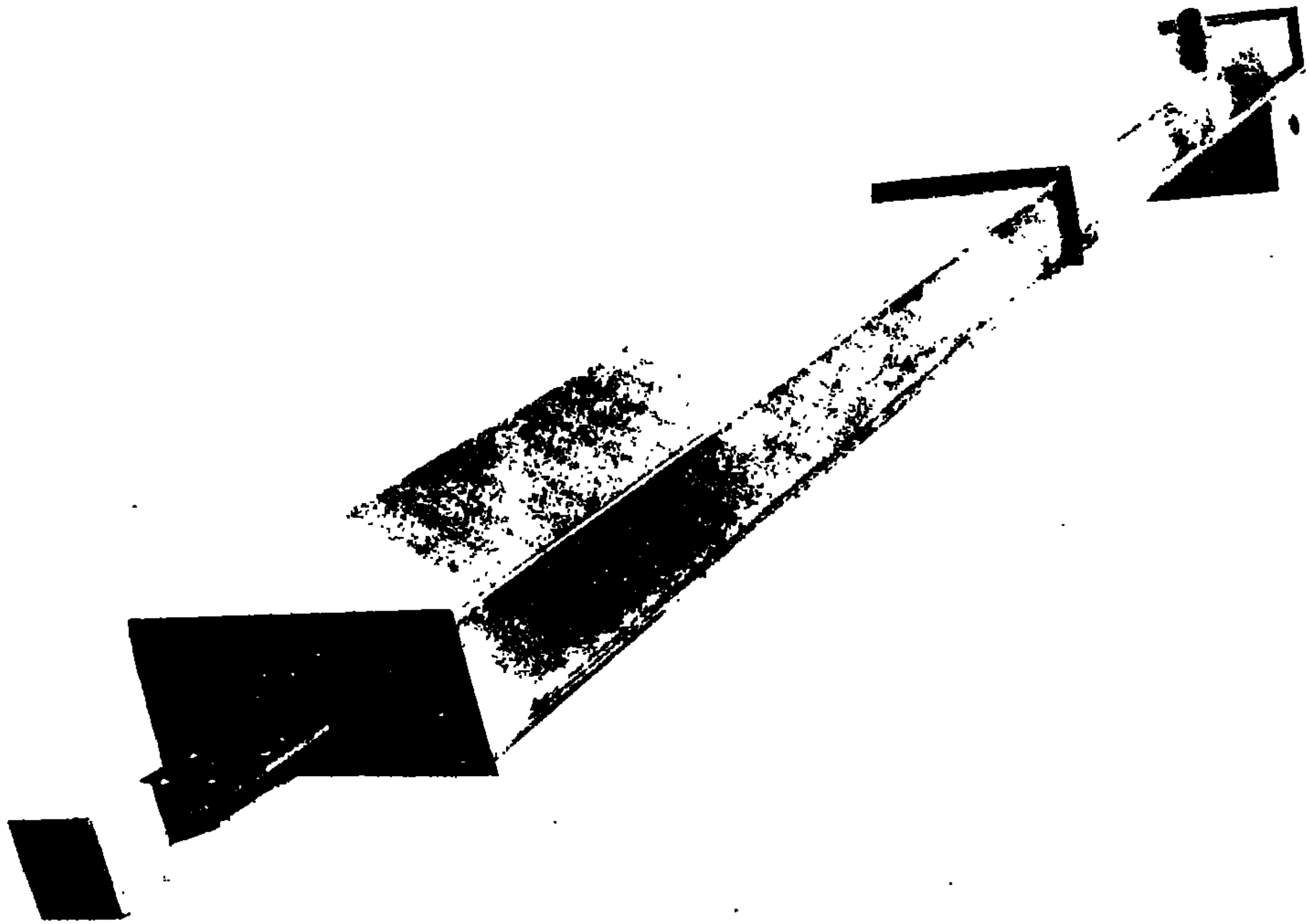

Figure 2. BIF Sanitrol Flow - Ratio Model 41 Sampler

Photograph courtesy of BIF Sanitrol.

General Comments: Manufacturer states unit was designed to sample raw or effluent wastes. A heavy duty model is available for applications where mixed wastes are present such as a paper mill where wood chips and fiber are present in waste liquid.

BIF Sanitrol Flow-Ratio Model 41 Evaluation

1. Clogging of sampling train is unlikely; however, the exposed chain-sprocket line is vulnerable to jamming by rags, debris, etc.

2. Unit provides a rigid obstruction to flow.

3. Unit should operate over full range of flows.

4. Movement of solids could jam unit.

5. No automatic starter; no self cleaning features.

6. Collects fixed size aliquots paced by built-in timer and composites them in a suitable container.

7. Does not appear well suited for collecting either floatables or coarser bottom solids.

8. No sample collector provided. Optional refrigerated sample container is available.

9. Unit is capable of manhole operation.

10. Unit cannot withstand total immersion.

11. Unit is not suitable for prolonged operation in freezing ambients.

12. 4.9m (16 ft) maximum lift puts some restriction on operating head conditions.

Designation:	BRAILSFORD MODEL DC-F
Manufacturer:	Brailsford and Company, Inc. Milton Road Rye, New York 10580 Phone (914) 967-1820
Sampler Intake:	End of 1.8m (6 ft) long sampling tube; weighted and fitted with 50 mesh strainer.
Gathering Method:	Suction lift by positive displacement pump.
Sample Lift:	Pump is capable of 3m (10 ft) lift but manufacturer recommends that lift be restricted to 0.9 to 2.1m (3 to 7 ft).
Line Size:	0.48 cm (3/16 in.) I.D.
Sample Flow Rate:	Adjustable from about 1.6 to 9.8 mℓ (0.1 to 0.6 cu in.) per minute.
Sample Capacity:	Pump output is collected in a 7.6ℓ (2 gal) jug.
Controls:	Pump stroke is adjustable by means of a slotted yoke on the piston rod. On/Off Switch.
Power Source:	6 VDC dry cell battery
Sample Refrigerator:	None
Construction Materials:	Stainless steel, teflon, vinyl, polyethylene; case is laminated Formica-wood construction, plastic rain boot.
Basic Dimensions:	48 x 30.5 x 24 cm (19x12x9.5 in.) weighs 8.5 kg (19 lbs) empty; portable.
Base Price:	$296.
General Comments:	Pump is valveless oscillating cylinder type. No lubrication is required for the life of the unit. Driven by a brushless D.C. motor of

patented design with a service life in excess of 3,000 hours. Continuous running pump is automatically shut off when sample jug is full.

Model EP is an explosion proof unit that is basically similar to the DC-F except for the housing. It also provides the pressure of a 10 cm (4 in.) water column on the sample to prevent the loss of volatile fractions or dissolved gases. A choice of 3.8ℓ (1 gal) sample containers (rectangular can or polyethylene bottle) is available. Price is $373.

A Model DU-2 is also available at $373. It is essentially a Model DC-F with the addition of an electronic timing circuit which can set the pumping rate for a sample frequency of between 1.75 and 13 minutes. An optional head detector is available for use with a weir to achieve a form of flow proportional sampling. Plugging in the head detector disconnects the timing circuit. The head detector is basically an array of magnetic switches connected to a series string of resistors and sealed within an insulating strip. A float containing a magnet slides up and down the strip as the water level changes, thereby altering the resistance in the circuit and, hence, the pumping rate. Price of the head detector is $98. The DU-2 can also be paced by an external flowmeter which provides momentary contact closures at a rate proportional to flow.

<u>Brailsford Model DC-F Evaluation</u>

1. 50 mesh strainer on end of sampling tube might be prone to clogging.

2. Minimal obstruction of flow.

3. Should operate reasonably well under all flow conditions, but low intake velocity will affect representatives of sample at high flow rates.

4. Movement of solids should not hamper operation.

5. Continuous flow unit, no automatic starter, no other self cleaning features.

6. Unit collects a continuous, low flow rate stream of sample and composites it in a 7.6ℓ (2 gal) jug. Model DU-2 offers several composite type options.

7. Unsuitable for collection of floatables or coarser bottom solids.

8. No refrigerator. Continuous flow eliminates cross contamination.

9. Appears fairly well suited for manhole operation.

10. Cannot withstand immersion.

11. Not suited for operation in freezing environments.

12. Recommended lift of 1.2m (4 ft) puts restriction on use of unit.

Designation:	BRAILSFORD MODEL EVS
Manufacturer:	Brailsford and Company, Inc. Milton Road Rye, New York 10580 Phone (914) 967-1820
Sampler Intake:	End of 3.7m (12 ft) long sampling tube fitted with a molded plastic inlet scoop-strainer to help prevent blockage by rags, paper, etc.
Gathering Method:	Suction lift by vacuum pump.
Sample Lift:	3.7m (12 ft) maximum.
Line Size:	0.48 (3/16 in.) I.D.
Sample Flow Rate:	Depends upon lift, but under 5 mℓ per minute.
Sample Capacity:	A 3.8ℓ (1 gal) composite sample is accumulated from small adjustable size aliquots.
Controls:	A control switch permits the choice of four timing intervals which will cause a 3.8ℓ (1 gal) sample to be collected in either 8, 16, 24 or 48 hours. The unit may also be paced by the head detector described under Model DC-F or an external flowmeter.
Power Source:	115 VAC or 12 VDC electricity.
Sample Refrigerator:	None
Construction Materials:	Sampling train is all plastic; case is laminated Formica-wood construction.
Basic Dimensions:	30.5 x 23 x 48 cm (12 x 9 x 19 in.); weighs 8.5 kg (19 lbs) empty; portable.
Basic Price:	\$520 115 VAC \$627 with N. Cad battery \$672 with N. Cad battery and AC power unit.

General Comments: Unit was designed for flows with a high percentage of suspended solids or where volatiles are present. Sample never passes through pump or valves or orifices which could become clogged. In operation, a small vacuum pump evacuates air from a small metering chamber to which the sample bottle and inlet tube are connected. When chamber is filled to a predetermined level, a magnetic sensing switch stops the pump and opens a vacuum relief valve so a portion of the sample flows into the jug and the remainder backflushes the inlet tube.

Brailsford Model EVS Evaluation

1. Specially designed inlet scoop-strainer may help prevent blockage. Rest of sample train should be free from clogging.

2. Minimal obstruction of flow.

3. Should operate reasonably well under all flow conditions, but fairly low intake velocities could affect representativeness of sample at high flow rates.

4. Movement of solids should not hamper operation.

5. No automatic starter - backflushing of inlet tube at end of each cycle provides a self cleaning function of sorts.

6. Unit collects a fixed time interval or flow proportional composite in a one gallon jug.

7. Unsuitable for collection of floatables or coarser bottom solids.

8. No refrigerator. Backflushing will help reduce cross contamination.

9. Appears well suited for manhole operation.

10. Unit cannot withstand immersion.

11. Not suitable for operation in freezing ambients.

12. Maximum lift of 3.7m (12 ft) puts some restrictions on use of unit.

Designation:	BVS MODEL PP-100
Manufacturer:	Brandywine Valley Sales Company 20 East Main Street Honey Brook, Pennsylvania 19344 Phone (215) 273-2841
Sampler Intake:	Plastic cylindrical sampling probe which is gravity filled. A row of small holes around the circumference near the bottom forms an inlet screen; weighted base.
Gathering Method:	Forced flow due to pneumatic ejection.
Sample Lift:	Up to 85m (280 ft); requires one pound of pressure for every 0.6m (2 ft) of vertical lift.
Line Size:	0.3 cm (1/8 in.) I.D.
Sample Flow Rate:	Depends upon pressure setting and lift.
Sample Capacity:	Sample chamber volume is 50 mℓ; sample composited in 9.5ℓ (2.5 gal) jug in standard model or 5.7ℓ (1.5 gal) jug in refrigerated model.
Controls:	Pressure regulator connecting gas supply is set between 0.35 and 9.8 kg/sq cm (5 and 140 psi) depending upon lift required; sampling interval timer is adjustable to allow from 2 seconds to 60 minutes to elapse between aliquots; manual on/off switch standard. Optional control package accepts signals from external flow meter or totalizer.
Power Source:	One 6.8 kg (15 lb) can of refrigerant is standard gas source; 12 VDC or 117 VAC required for refrigerated models or flow proportional control option.
Sample Refrigerator:	Model PPR-100 offers an absorption refrigerator cooled sample case.

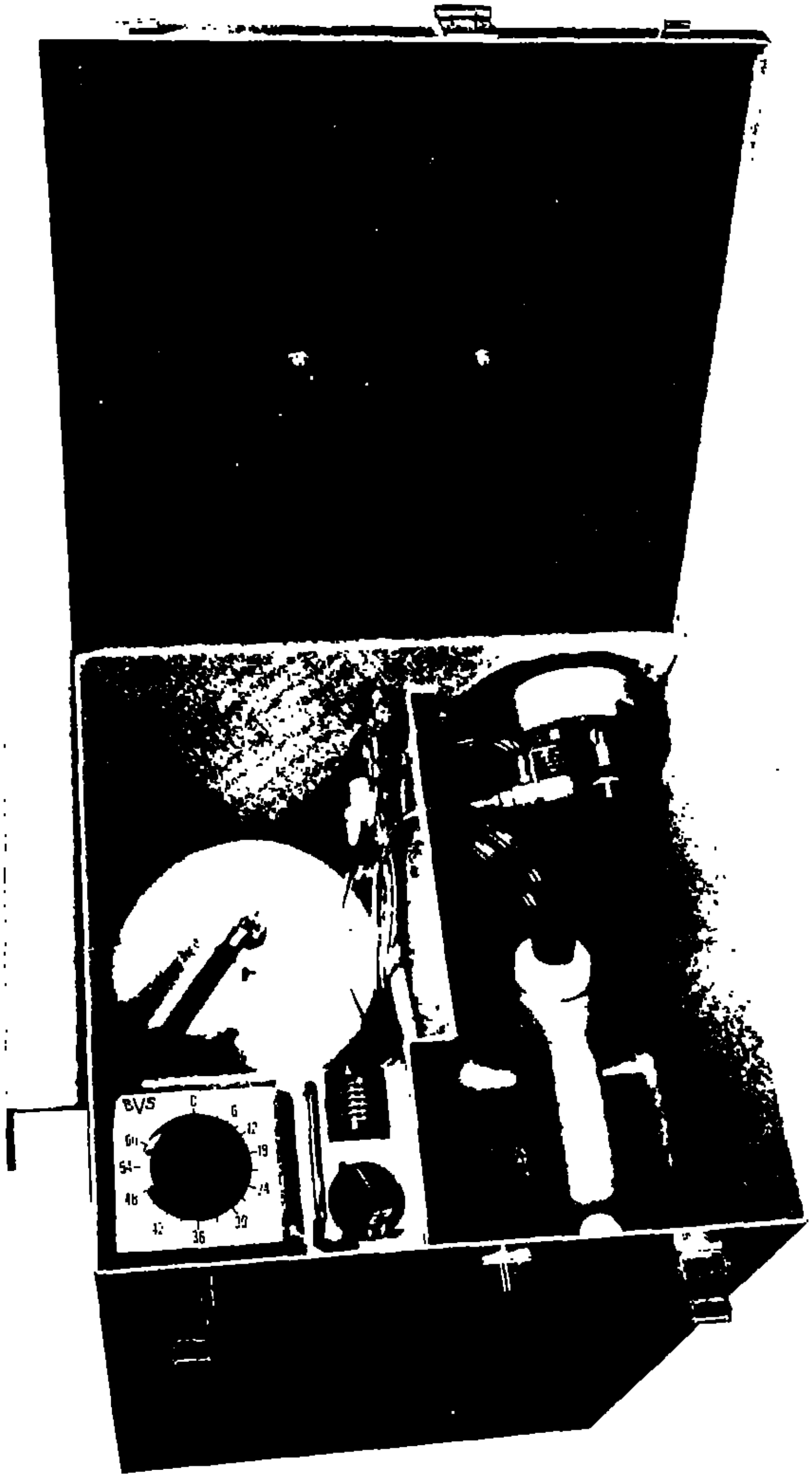

Figure 3. BVS Model PP-100 Sampler

Photograph Courtesy of Brandywine Valley Sales Company

Construction Materials: Sampling probe is PVC standard, teflon or stainless steel available; plastic sampling line standard, teflon available; polyethylene sample container; Armorhide finished aluminum case.

Basic Dimensions: Non-refrigerated - 35.6 x 35.6 x 53.3 cm (14x14x21 in.); refrigerated - 43.2 x 55.9 x 43.2 cm (17 x 22 x 17 in.); both models portable.

Base Price: $853 for basic unit including 50 mℓ sampling probe, one 6.8 kg (15 lb) cylinder of R-12, and 3-6.1m (20 ft) lengths of tubing. Refrigerated model PPR-100 is $1150. Add $100 for winterizing system; $275 for solid state control package for flow proportional operation.

General Comments: Timing circuits are controlled by fluidic and pneumatic components. Absorption refrigerator has no moving parts. After each aliquot is gathered, the inlet strainer of the sampling probe is purged by vent pressure from timing valve. Two year parts and labor warranty. Alternate sampling probes available include a surface sampling probe for surface oil, vertical stratum sampling probe for sampling at 15 cm (6 in.) depth intervals, and float mounted probes for sample quantity accuracy that is independent of head.

BVS Model PP-100 Evaluation

1. Sampling probe is vulnerable to blockage of a number of sampling ports at one time by paper, rags, plastic, etc. Sampling train is unobstructed 0.3 cm (1/8 in.) I.D. tube which should pass small solids. No pump to clog.

2. Obstruction to flow will depend upon user mounting of intake.

3. Sampling chamber will fill immediately following intake screen purge at end of previous cycle. Circulation of flow through chamber would appear to be limited, resulting in a sample not necessarily representative of conditions in the sewer at the time of the next triggering signal.

4. Movement of solids should not hamper operation.

5. No automatic starter. A self-cleaning feature for the intake screen is accomplished by using vent pressure from the timing valve to purge it.

6. Collects fixed size aliquots at either preset time intervals or paced by external flowmeter if equipped with control option, and composites them in a suitable container.

7. Special sampling probe available for surface oil sampling, etc.; appears unsuitable for sampling coarser bottom solids.

8. Automatic refrigerated sample compartment available, but sample size is reduced. Some cross-contamination appears likely.

9. Unit appears capable of manhole operation.

10. Case is weatherproof but will not withstand total immersion.

11. Optional winterizing kit is available for use in very cold ambients.

12. Unit has a very wide range of operating head conditions. High lifts will result in faster depletion of gas supply.

Designation: BVS MODEL PE-400

Manufacturer:

Brandywine Valley Sales Company
20 East Main Street
Honey Brook, Pennsylvania 19344
Phone (215) 273-2841

Sampler Intake: PVC screen over pump inlet.

Gathering Method: Forced flow from submersible pump.

Sample Lift: 9.8m (32 ft) maximum.

Line Size: 1.3 cm (1/2 in.) I.D. inlet hose.

Sample Flow Rate: 3.8-7.6 ℓpm (1-2 gpm) typical.

Sample Capacity: Aliquot volume is a function of the preset diversion time; sample composited in 9.5ℓ (2.5 gal) container.

Controls: Unit operates on a continuous flow principle, returning uncollected flow to waste. Sample is pumped through a stainless steel, non-clogging diverter valve. Upon receiving a signal from either the built-in timer or an external flowmeter, the unit diverts the flow for a preset period of time (adjustable from 0.02 to 1.0 seconds) to the sample container.

When operating in the timed sampling mode, the sampling frequency rate is continuously adjustable from 0.2 seconds to 60 hours. When operating in the flow-proportional mode the sampler is triggered directly by the external flow meter.

Power Source: 115 VAC electricity.

Sample Refrigerator: Model PER-400 is refrigerated, but case is not weather-proof.

Construction Materials:	Sampling train, PVC, stainless steel, plastic, polyethylene, cabinet is aluminum with Armorhide finish.
Basic Dimensions:	Non-refrigerated - 35.6 x 35.6 x 53.3 cm (14 x 14 x 21 in.); refrigerated - 53.3 x 58.4 x 96.5 cm (21 x 23 x 38 in.); both models portable.
Base Price:	$1,500 including 6.1m (20ft) of 2.1 cm (13/16 in.) OD x 1.3 cm (1/2 in.) ID nylon reinforced plastic inlet tubing, 6.1m (20 ft) of 3.5 cm (1-3/8 in.) OD x 2.5 cm (1 in.) ID nylon reinforced plastic tubing for waste return, clamps, pump support bracket, pump strainer, pump with 11m (36 ft) cord, and flow proportional connection cable. For refrigerator add $300; for 30 day strip chart recorder add $260. Model PE-500 at $1,700 is similar but designed for high flow rates and solids sizes to 1.9 cm (3/4 in.) and does not include pump, tubing, clamps or sample container. Model PE-600 at $1,950 is similar to Model PE-500 but has dual-solenoid diversion valve and passes solids to 4.4 cm (1.75 in.).
General Comments:	Submersible pump has magnetic drive, is self-priming. Manufacturer claims design will handle solids to 0.95 cm (3/8 in.) diameter. Model SE-400 is a refrigerated version designed for fixed installations and priced at $3,000. It is housed in a 66 x 76 x 122 cm (26x30x48 in.) weather-proof case on 20 cm (8 in.) legs with a thermostatically controlled heater, vent system to control moisture, and manual sample take-off line. Model SE-800 is similar to SE-400 but can take 24-500 mℓ discrete samples or a 19ℓ (5 gal) composite

sample. It has an inkless strip-chart event recorder and is priced at $5,650. Model SE-500 is similar to PE-500 with additional features of SE-400 and is priced at $3,200; Model SE-600 is similar to PE-600 with additional features of SE-400 except 19ℓ (5 gal) sample container and is priced at $3,600. SE prices include installation, start-up, and operator training by BVS. Two-year warranty on parts and labor for all models. Life-time warranty on sample diversion valve.

BVS Model PE-400 Evaluation

1. Large sampling screen over pump inlet can tolerate blockage of a number of ports and still function. Pump and tubing should be free from clogging.

2. Submersible pump and screen present an obstruction to the flow.

3. Should be capable of operation over the full range of flows.

4. Movement of small solids should not affect operation; large objects could damage (or even physically destroy) the in-water portion unless special protection is provided by user.

5. No automatic starter since designed for continuous flow. Continuous flow serves a self-cleaning function of all except line from diverter to sample bottle.

6. Collects spot samples paced either by built-in timer or external flowmeter and composites them in a suitable container. SE-800 collects 24 discrete samples.

7. Appears unsuitable for collection of either floatables or coarser bottom solids.

8. Automatic refrigerated sample compartment available. Cross-contamination should not be too great.

9. Portable unit appears capable of manhole operation.

10. Cannot withstand total immersion.

11. Can operate in freezing ambients if fitted with winterizing kit.

12. Upper lift limit of 9.8m (32 ft) does not pose a great restriction on operating head conditions.